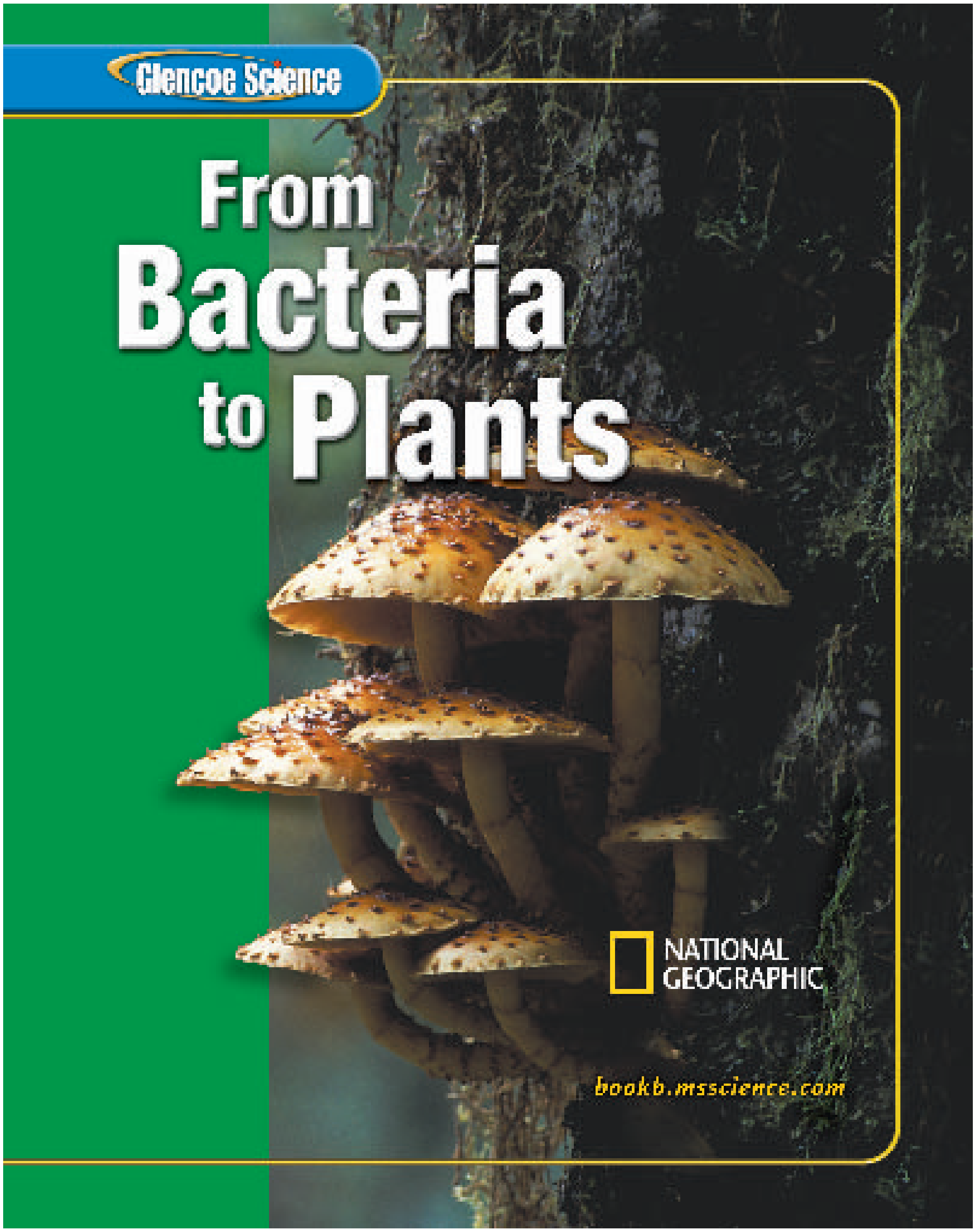

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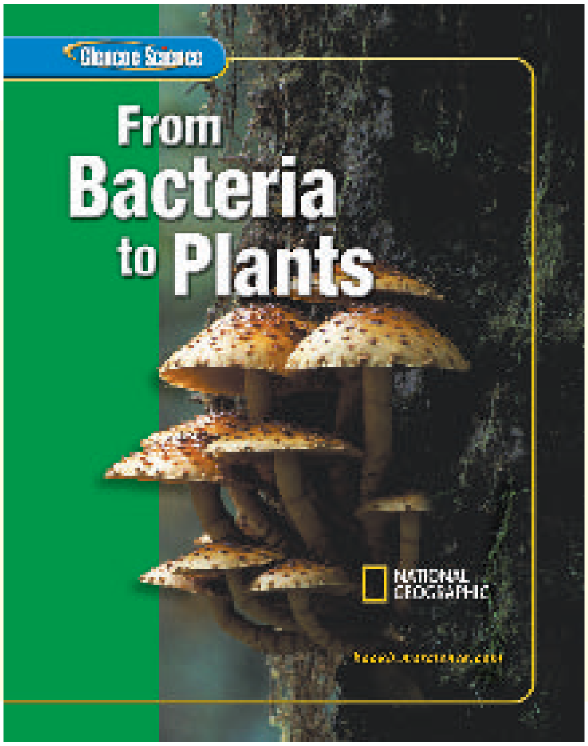
Glencoe Science

From Bacteria to Plants

Lichens and club fungi are growing on the bark of this tree. In some cases, the two organisms that make up a lichen can live separately, but look very different than the lichen. Club fungi are saprobes, which play a vital role in the decomposition of litter, wood, and dung.



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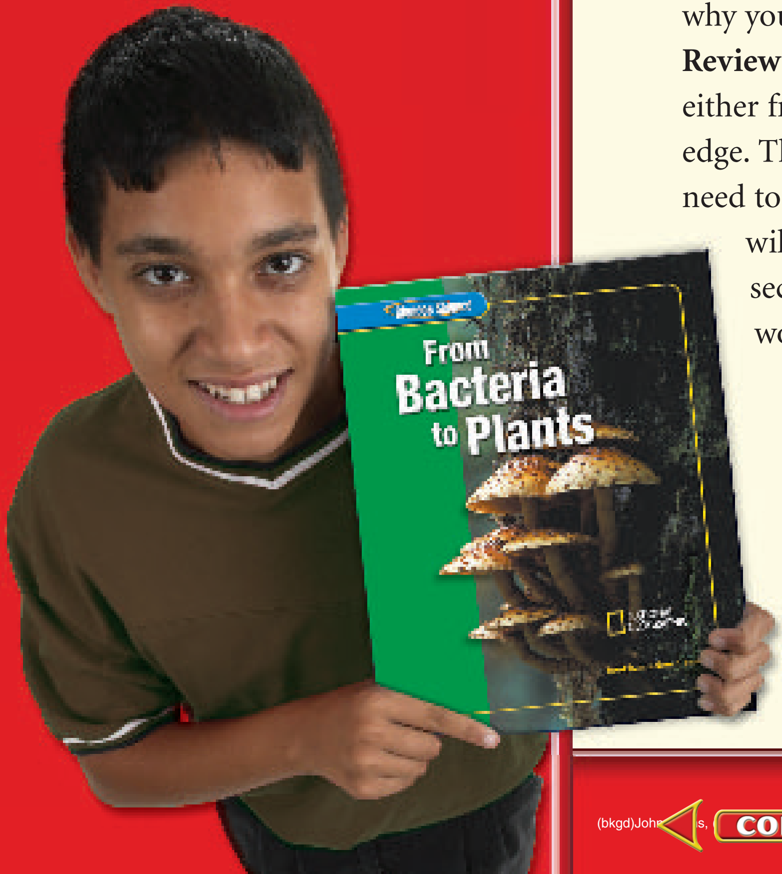
HOW TO...

Use Your Science Book

Why do I need my science book?

Have you ever been in class and not understood all of what was presented? Or, you understood everything in class, but at home, got stuck on how to answer a question? Maybe you just wondered when you were ever going to use this stuff?

These next few pages are designed to help you understand everything your science book can be used for . . . besides a paperweight!



Before You Read

- **Chapter Opener** Science is occurring all around you, and the opening photo of each chapter will preview the science you will be learning about. The **Chapter Preview** will give you an idea of what you will be learning about, and you can try the **Launch Lab** to help get your brain headed in the right direction. The **Foldables** exercise is a fun way to keep you organized.
- **Section Opener** Chapters are divided into two to four sections. The **As You Read** in the margin of the first page of each section will let you know what is most important in the section. It is divided into four parts. **What You'll Learn** will tell you the major topics you will be covering. **Why It's Important** will remind you why you are studying this in the first place! The **Review Vocabulary** word is a word you already know, either from your science studies or your prior knowledge. The **New Vocabulary** words are words that you need to learn to understand this section. These words will be in **boldfaced** print and highlighted in the section. Make a note to yourself to recognize these words as you are reading the section.

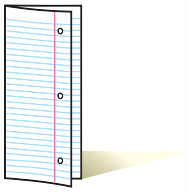
As You Read

- **Headings** Each section has a title in large red letters, and is further divided into blue titles and small red titles at the beginnings of some paragraphs. To help you study, make an outline of the headings and subheadings.
- **Margins** In the margins of your text, you will find many helpful resources. The **Science Online** exercises and **Integrate** activities help you explore the topics you are studying. **MiniLabs** reinforce the science concepts you have learned.
- **Building Skills** You also will find an **Applying Math** or **Applying Science** activity in each chapter. This gives you extra practice using your new knowledge, and helps prepare you for standardized tests.
- **Student Resources** At the end of the book you will find **Student Resources** to help you throughout your studies. These include **Science, Technology,** and **Math Skill Handbooks,** an **English/Spanish Glossary,** and an **Index.** Also, use your **Foldables** as a resource. It will help you organize information, and review before a test.
- **In Class** Remember, you can always ask your teacher to explain anything you don't understand.

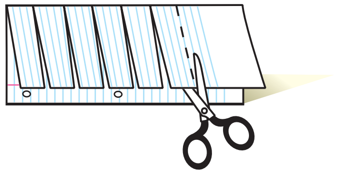
FOLDABLES™ Study Organizer

Science Vocabulary Make the following Foldable to help you understand the vocabulary terms in this chapter.

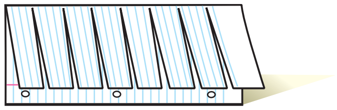
STEP 1 **Fold** a vertical sheet of notebook paper from side to side.



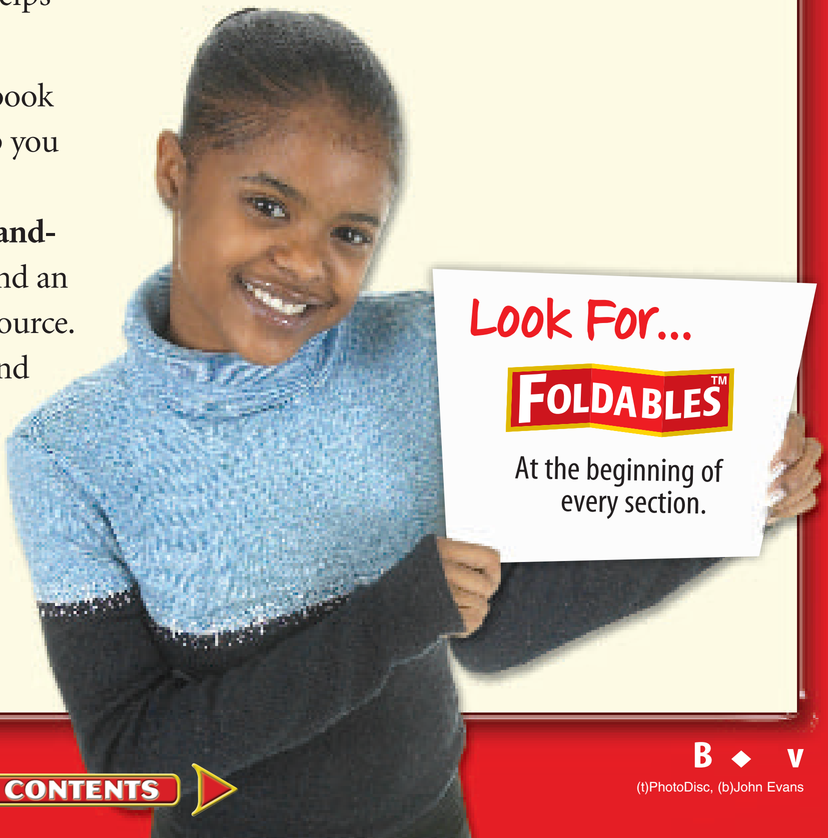
STEP 2 **Cut** along every third line of only the top layer to form tabs.



STEP 3 **Label** each tab with a vocabulary word from the chapter.



Build Vocabulary As you read the chapter, list the vocabulary words on the tabs. As you learn the definitions, write them under the tab for each vocabulary word.



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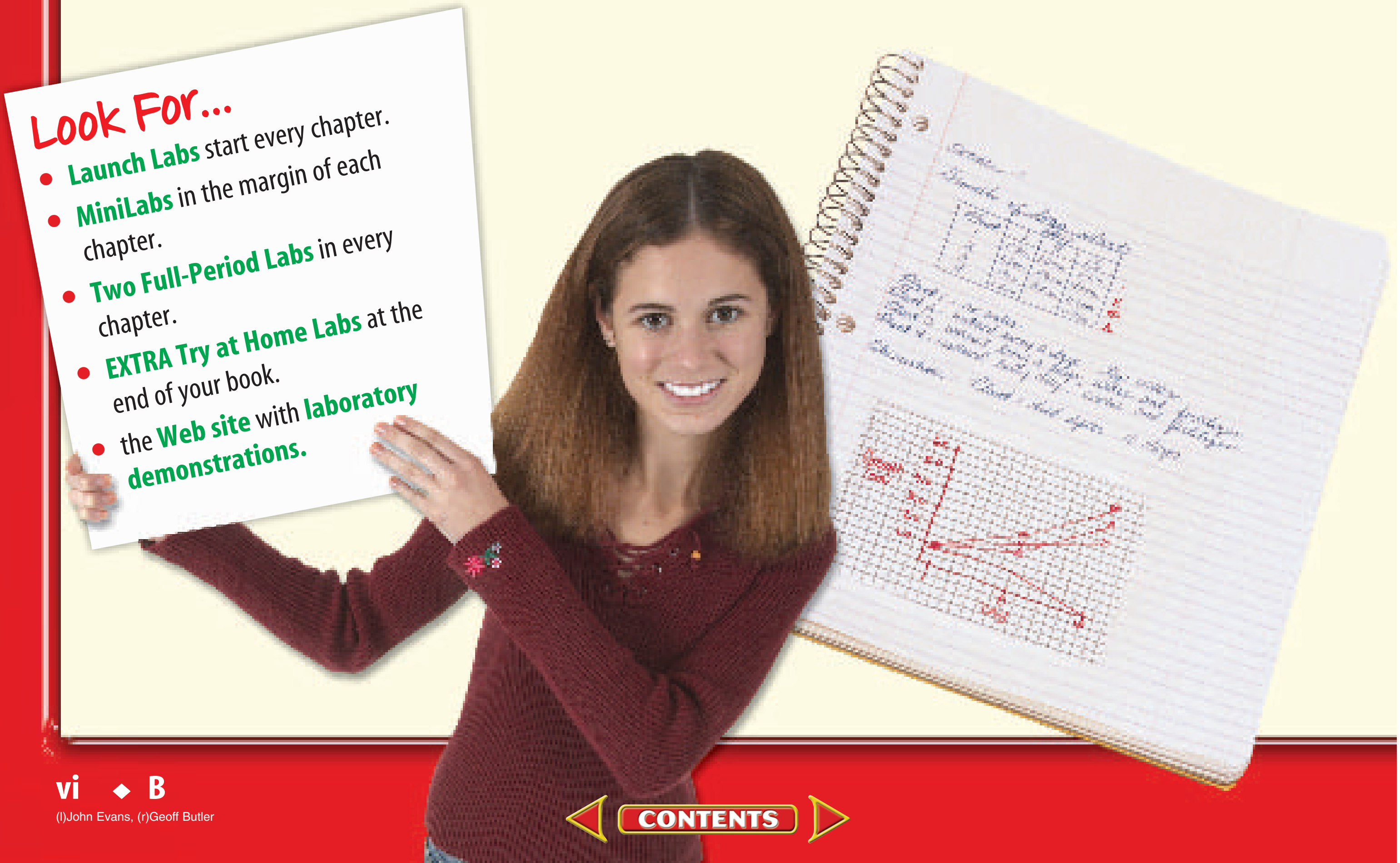
(t)PhotoDisc, (b)John Evans

In Lab

Working in the laboratory is one of the best ways to understand the concepts you are studying. Your book will be your guide through your laboratory experiences, and help you begin to think like a scientist. In it, you not only will find the steps necessary to follow the investigations, but you also will find helpful tips to make the most of your time.

- Each lab provides you with a **Real-World Question** to remind you that science is something you use every day, not just in class. This may lead to many more questions about how things happen in your world.
- Remember, experiments do not always produce the result you expect. Scientists have made many discoveries based on investigations with unexpected results. You can try the experiment again to make sure your results were accurate, or perhaps form a new hypothesis to test.
- Keeping a **Science Journal** is how scientists keep accurate records of observations and data. In your journal, you also can write any questions that may arise during your investigation. This is a great method of reminding yourself to find the answers later.



(l)John Evans, (r)Geoff Butler

Before a Test

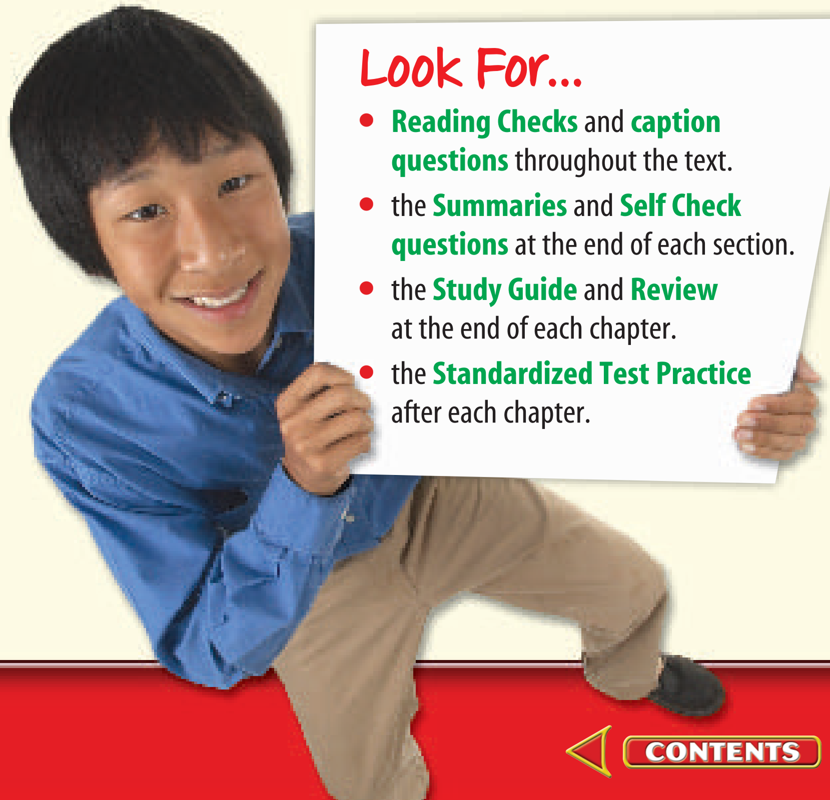
Admit it! You don't like to take tests! However, there *are* ways to review that make them less painful. Your book will help you be more successful taking tests if you use the resources provided to you.

- Review all of the **New Vocabulary** words and be sure you understand their definitions.
- Review the notes you've taken on your **Foldables,** in class, and in lab. Write down any question that you still need answered.
- Review the **Summaries** and **Self Check questions** at the end of each section.
- Study the concepts presented in the chapter by reading the **Study Guide** and answering the questions in the **Chapter Review.**

a or b?

?

T or F?



Look For...

- **Reading Checks** and **caption questions** throughout the text.
- the **Summaries** and **Self Check questions** at the end of each section.
- the **Study Guide** and **Review** at the end of each chapter.
- the **Standardized Test Practice** after each chapter.

(l)John Evans, (r)PhotoDisc

Scavenger HUNT

Let's Get Started

To help you find the information you need quickly, use the Scavenger Hunt below to learn where things are located in Chapter 1.

1. What is the title of this chapter?
2. What will you learn in Section 1?
3. Sometimes you may ask, "Why am I learning this?" State a reason why the concepts from Section 2 are important.
4. What is the main topic presented in Section 2?
5. How many reading checks are in Section 1?
6. What is the Web address where you can find extra information?
7. What is the main heading above the sixth paragraph in Section 2?
8. There is an integration with another subject mentioned in one of the margins of the chapter. What subject is it?
9. List the new vocabulary words presented in Section 2.
10. List the safety symbols presented in the first Lab.
11. Where would you find a Self Check to be sure you understand the section?
12. Suppose you're doing the Self Check and you have a question about concept mapping. Where could you find help?
13. On what pages are the Chapter Study Guide and Chapter Review?
14. Look in the Table of Contents to find out on which page Section 2 of the chapter begins.
15. You complete the Chapter Review to study for your chapter test. Where could you find another quiz for more practice?

PhotoDisc

Teacher Advisory Board

The Teacher Advisory Board gave the editorial staff and design team feedback on the content and design of the Student Edition. They provided valuable input in the development of the 2005 edition of ***Glencoe Science.***

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The Student Advisory Board gave the editorial staff and design team feedback on the design of the Student Edition. We thank these students for their hard work and creative suggestions in making the 2005 edition of ***Glencoe Science*** student friendly.

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The Glencoe middle school science Student Advisory Board taking a timeout at COSI, a science museum in Columbus, Ohio.

Aaron Haupt Photography

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Greg Vaughn/Getty Images

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Content Details

Mark Steinmetz

The NATURE OF SCIENCE

Experimentation

Plant Communication

Figure 1 Acacia trees communicate by emitting a gas that travels to surrounding trees. This communication helps protect them from predators.

For hundreds of years, scientists have been performing experiments to learn more about plants, such as how they function and respond to their environment. Early experiments were limited to just observations. Today, scientists experiment with plants in many ways to learn more about their biology. Recently, scientists have been investigating the idea of plant communication and asking questions like "Is it possible for plants to communicate with each other?"

Evidence of Communication

Observations of certain species of plants reacting to predators or disease have interested scientists who were conducting experiments in an attempt to understand the exact nature of plant communication. In 1990, researchers discovered evidence of plant communication. As part of their defense against predators, acacia (ah KAY shah) trees produce a toxin—a poisonous substance. In response to a predator, such as an antelope nibbling on its leaves, an acacia tree releases a gas that stimulates other acacia trees up to 50 m away to produce extra toxin within minutes. Although the toxin initially does not prevent the antelopes from eating the acacia leaves, if the antelopes consume enough of the toxin, it can kill them. Thus, the chemical warning system used by the acacias can help guard these trees against future attacks.

Figure 2 A tobacco plant produces methyl salicylate when infected with TMV.

(t)Carol Cawthra/Animals Animals, (b)Grant Heilman Photography

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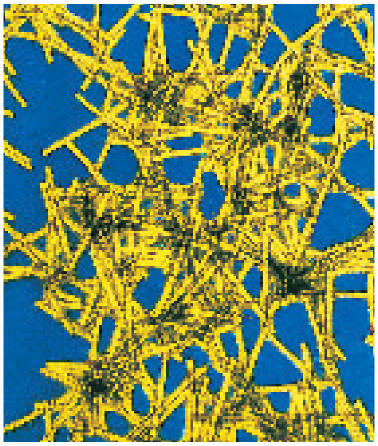
Another Warning System

Other evidence suggests that tobacco plants also might use a chemical warning system. One of the most common problems of tobacco and several vegetable and ornamental plants is the tobacco mosaic virus (TMV). TMV causes blisters on the tobacco plant, which disfigure its leaves and keep it from growing to its full size. Recently, scientists have discovered that TMV-infected tobacco plants produce a chemical that may warn nearby healthy tobacco plants of the presence of the virus, and stimulate them to produce substances to help fight against the virus.

Researchers at a university tested some TMV-infected tobacco plants. They noted the presence of a gas called methyl salicylate (MEH thul • suh LIH suh late), also known as oil of wintergreen, in the air near TMV-infected plants. The researchers hypothesized that methyl salicylate is a chemical warning signal of a TMV infection.



Color-enhanced SEM Magnification: 34,000×

Figure 3 These tobacco mosaic viruses are magnified 34,000 times.

Testing the Hypothesis

To test this hypothesis, they inoculated some healthy tobacco plants with TMV and monitored the air around them for methyl salicylate. They detected the gas above infected plants and found that the production of the gas increased as leaf damage progressed. The gas was not produced by healthy plants. The researchers allowed the gas to move through the air from infected to healthy plants. They found a connection between the presence of methyl salicylate and responses in healthy plants. As the levels of methyl salicylate increased, the healthy plants began to produce substances that could help them fight viruses. These results supported the hypothesis that methyl salicylate is a warning signal because it was produced by infected plants and was linked to resistance to the virus in healthy plants.

Figure 4 This tobacco leaf shows symptoms of a TMV infection.

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my ... ss/Science Photo Library/Photo Researchers, (b)Jack M. Bostracr/Visuals Unlimited, Inc.

The NATURE OF SCIENCE

The Study of Living Things

The study of all living things and their interaction with their environment is life science. In this book, you will learn about the characteristics of bacteria, protists, fungi, and plants.

Experimentation

Scientists try to find answers to their questions by performing experiments and recording the results. An experiment's procedure must be carefully planned before it is begun. First, scientists must identify a question to be answered or a problem to be solved. The proposed answer to the question or explanation of the problem is called a hypothesis. A hypothesis must be testable to be valid. Scientists design an experiment that will support or disprove their hypothesis. The scientists studying tobacco plants tested their hypothesis that methyl salicylate is a chemical warning signal produced by TMV-infected plants.

Figure 5 Scientists experiment with plants to learn more about their biology.

Sampling

If a hypothesis refers to a very large number of objects or members of a species, scientists cannot test every one of them. Instead, they use sampling—they test their hypothesis on a smaller, representative group. The university scientists were not able to test every tobacco plant. Instead, they used a group of plants that were grown in a greenhouse.

Variables and Controls in an Experiment

Scientists must make sure that only one factor affects the results of an experiment. The factor that the scientists change in the experiment is called the independent variable. The dependent variable is what the scientists measure or observe to obtain the results. A constant is any factor in an experiment that always remains the same. The observations and measurements that scientists make are called data. A control is an additional experiment performed for comparison. A control has all factors of the original experiment except the variables.

Kevin Fitzsimons
CONTENTS

Determining Variables

In the experiment on tobacco plants, the independent variable was the addition of the tobacco mosaic virus to the healthy plants. The dependent variable was the production of methyl salicylate gas. The effect of this gas on healthy tobacco plants provided evidence for its function as a signal. Factors that were constant included the growth conditions for the tobacco plants before and after some were infected. The control was the uninfected plants. Because the only difference in the treatment of the plants was inoculation with TMV, it can be said that the independent variable is the cause of the production of methyl salicylate, the dependent variable. If more than one factor is changed, however, the dependent variable's change can't be credited to only the independent variable. This makes the experiment's results less reliable.

Figure 6 A scientist often uses a computer to record and analyze data.

Drawing a Conclusion

A conclusion is what has been learned as the result of an experiment. Conclusions should be based only on data. They must be free of bias—anything that keeps researchers from making objective decisions. Using what they had learned from their experiments, the scientists studying tobacco mosaic virus concluded that their hypothesis was correct.

To be certain about their conclusions, scientists must have safeguards. One safeguard is to repeat an experiment, like the university scientists did. Hypotheses are not accepted until the experiments have been repeated several times and they produce the same results each time.

Because oil of wintergreen is not known to be dangerous to humans, using oil of wintergreen to prevent TMV infection may be practical as well as scientifically sound. Scientists are investigating how oil of wintergreen might be used as an alternative pesticide.

Figure 7 Someday, spraying oil of wintergreen might prevent the spread of the tobacco mosaic virus.

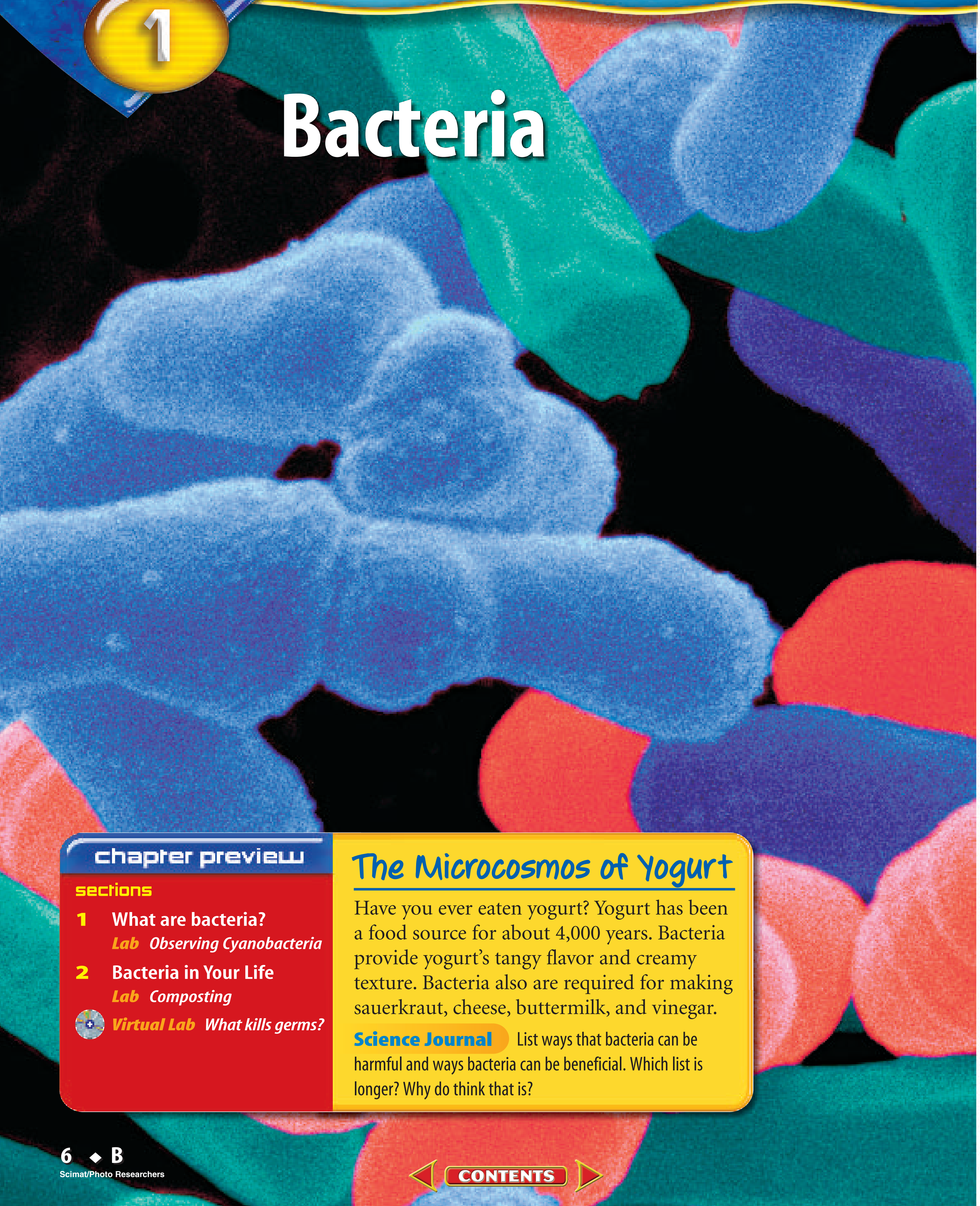
You Do It

Describe a procedure you would use to test this hypothesis: Vaccine X protects plants from being infected by the deadly plant virus Z. What would be your independent and dependent variables? How could you establish controls in your experiment?

(t)Dwayne Newton/PhotoEdit, (b)Jim Strawser/Grant Heilman Photography, Inc.

chapter 1

Bacteria



chapter preview

sections

1 What are bacteria?
Lab *Observing Cyanobacteria*

2 Bacteria in Your Life
Lab *Composting*

Virtual Lab *What kills germs?*

The Microcosmos of Yogurt

Have you ever eaten yogurt? Yogurt has been a food source for about 4,000 years. Bacteria provide yogurt's tangy flavor and creamy texture. Bacteria also are required for making sauerkraut, cheese, buttermilk, and vinegar.

Science Journal List ways that bacteria can be harmful and ways bacteria can be beneficial. Which list is longer? Why do think that is?

Scimat/Photo Researchers

Start-Up Activities

Launch LAB

Model a Bacterium's Slime Layer

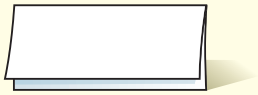
Bacterial cells have a gelatinlike, protective coating on the outside of their cell walls. In some cases, the coating is thin and is referred to as a slime layer. A slime layer can help a bacterium attach to other surfaces. Dental plaque forms when bacteria with slime layers stick to teeth and multiply there. A slime layer also can reduce water loss from a bacterium. In this lab you will make a model of a bacterium's slime layer.

1. Cut two 2-cm-wide strips from the long side of a synthetic kitchen sponge.
2. Soak both strips in water. Remove them from the water and squeeze out the excess water. Both strips should be damp.
3. Completely coat one strip with hair-styling gel. Do not coat the other strip.
4. Place both strips on a plate (not paper) and leave them overnight.
5. **Think Critically** Record your observations of the two sponge strips in your Science Journal. Infer how a slime layer protects a bacterial cell from drying out. What environmental conditions are best for survival of bacteria?

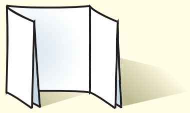
FOLDABLES™ Study Organizer

Archaebacteria and Eubacteria Make the following Foldable to compare and contrast the characteristics of bacteria.

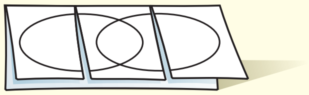
STEP 1 **Fold** one sheet of paper lengthwise.



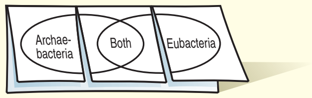
STEP 2 **Fold** into thirds.



STEP 3 **Unfold and draw** overlapping ovals. Cut the top sheet along the folds.



STEP 4 **Label** the ovals as shown.



Construct a Venn Diagram As you read the chapter, list the characteristics unique to archaebacteria under the left tab, those unique to eubacteria under the right tab, and those characteristics common to both under the middle tab.

Science Online Preview this chapter's content and activities at bookb.msscience.com

Scimat/Photo Researchers

section 1

What are bacteria?

as you read

What You'll Learn

- Identify the characteristics of bacterial cells.
- Compare and contrast aerobic and anaerobic organisms.

Why It's Important

Bacteria are found almost everywhere and affect all living things.

Review Vocabulary
prokaryotic: cells without membrane-bound organelles

New Vocabulary
- flagella
- fission
- aerobe
- anaerobe

Characteristics of Bacteria

For thousands of years people did not understand what caused disease. They did not understand the process of decomposition or what happened when food spoiled. It wasn't until the latter half of the seventeenth century that Antonie van Leeuwenhoek, a Dutch merchant, discovered the world of bacteria. Leeuwenhoek observed scrapings from his teeth using his simple microscope. Although he didn't know it at that time, some of the tiny swimming organisms he observed were bacteria. After Leeuwenhoek's discovery, it was another hundred years before bacteria were proven to be living cells that carry on all of the processes of life.

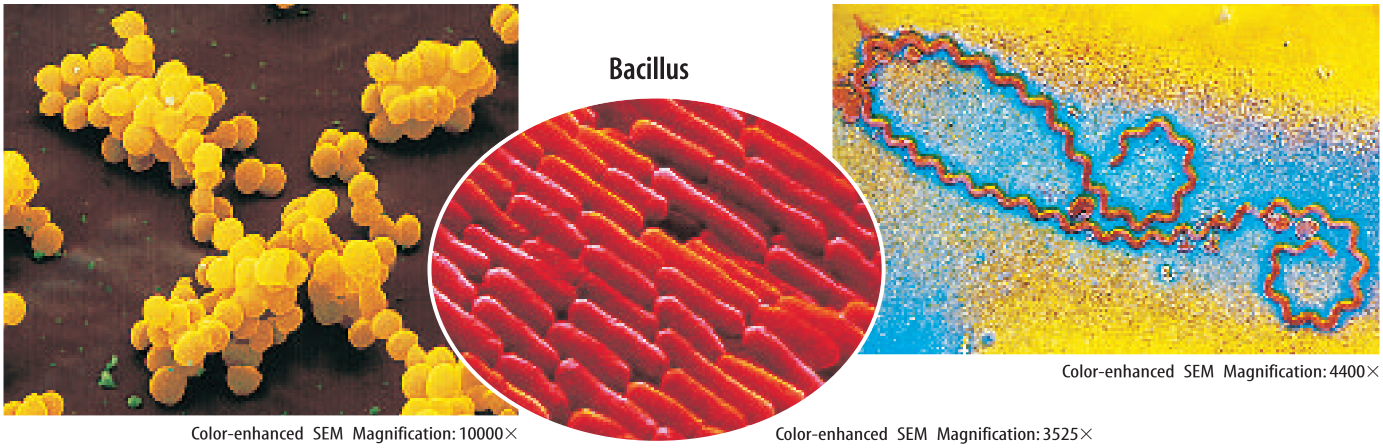
Where do bacteria live? Bacteria are almost everywhere—in the air, in foods that you eat and drink, and on the surfaces of things you touch. They are even found thousands of meters underground and at great ocean depths. A shovelful of soil contains billions of them. Your skin has about 100,000 bacteria per square centimeter, and millions of other bacteria live in your body. Some types of bacteria live in extreme environments where few other organisms can survive. Some heat-loving bacteria live in hot springs or hydrothermal vents—places where water temperature exceeds 100°C. Others can live in cold water or soil at 0°C. Some bacteria live in very salty water, like that of the Dead Sea. One type of bacteria lives in water that drains from coal mines, which is extremely acidic at a pH of 1.

Figure 1 Bacteria can be found in almost any environment.
List *common terms that could be used to describe these cell shapes.*

Coccus

Bacillus

Spirillum



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(l)Oliver Meckes/Photo Researchers, (c,r)CNRI/Science Photo Library/Photo Researchers

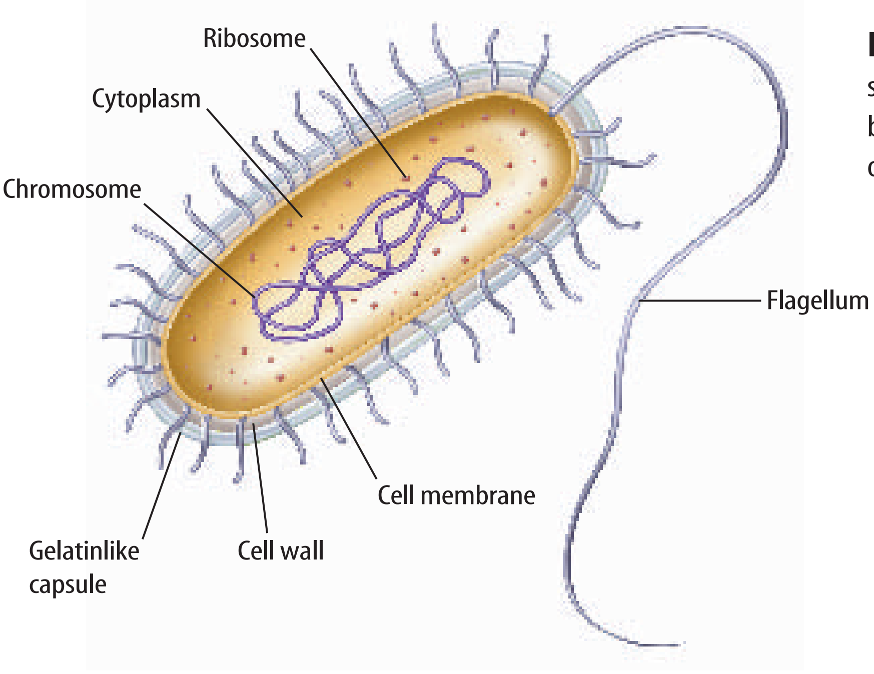

Figure 2 Bacterial cells are much smaller than eukaryotic cells. Most bacteria are about the size of some organelles found inside eukaryotic cells.

Structure of Bacterial Cells Bacteria normally have three basic shapes—spheres, rods, and spirals, as shown in **Figure 1.** Sphere-shaped bacteria are called cocci (KAHK si) (singular, *coccus*), rod-shaped bacteria are called bacilli (buh SIH li) (singular, *bacillus*), and spiral-shaped bacteria are called spirilla (spi RIH luh) (singular, *spirillum*). Bacteria are smaller than plant or animal cells. They are one-celled organisms that occur alone or in chains or groups.

A typical bacterial cell contains cytoplasm surrounded by a cell membrane and a cell wall, as shown in **Figure 2.** Bacterial cells are classified as prokaryotic because they do not contain a membrane-bound nucleus or other membrane-bound internal structures called organelles. Most of the genetic material of a bacterial cell is in its one circular chromosome found in the cytoplasm. Many bacteria also have a smaller circular piece of DNA called a plasmid. Ribosomes also are found in a bacterial cell's cytoplasm.

Special Features Some bacteria, like the type that causes pneumonia, have a thick, gelatinlike capsule around the cell wall. A capsule can help protect the bacterium from other cells that try to destroy it. The capsule, along with hairlike projections found on the surface of many bacteria, also can help them stick to surfaces. Some bacteria also have an outer coating called a slime layer. Like a capsule, a slime layer enables a bacterium to stick to surfaces and reduces water loss. Many bacteria that live in moist conditions also have whiplike tails called **flagella** to help them move.

Reading Check *How do bacteria use flagella?*

Mini LAB

Modeling Bacteria Size

Procedure

1. One human hair is about 0.1 mm wide. Use a **meterstick** to measure a piece of **yarn or string** that is 10 m long. This yarn represents the width of your hair.
2. One type of bacteria is 2 micrometers long (1 micrometer = 0.000001 m). Measure another piece of yarn or string that is 20 cm long. This piece represents the length of the bacterium.
3. Find a large area where you can lay the two pieces of yarn or string next to each other and compare them.

Analysis

1. Calculate how much smaller the bacterium is than the width of your hair.
2. In your **Science Journal,** describe why a model is helpful to understand how small bacteria are.

Try at Home

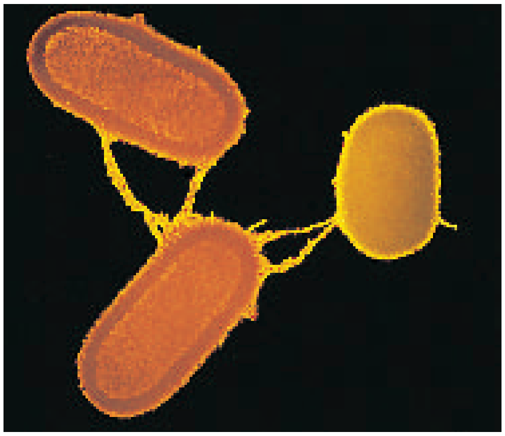

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Figure 3 Before dividing, these bacteria are exchanging DNA through the tubes that join them. This process is called conjugation.

Reproduction Bacteria usually reproduce by fission. **Fission** is a process that produces two new cells with genetic material identical to each other and that of the original cell. It is the simplest form of asexual reproduction.

Some bacteria exchange genetic material through a process similar to sexual reproduction, as shown in **Figure 3.** Two bacteria line up beside each other and exchange DNA through a fine tube. This results in cells with different combinations of genetic material than they had before the exchange. As a result, the bacteria may acquire variations that give them an advantage for survival.

How Bacteria Obtain Food and Energy Bacteria obtain food in a variety of ways. Some make their food and others get it from the environment. Bacteria that contain chlorophyll or other pigments make their own food using energy from the Sun. Other bacteria use energy from chemical reactions to make food. Bacteria and other organisms that can make their own food are called producers.

Most bacteria are consumers. They do not make their own food. Some break down dead organisms to obtain energy. Others live as parasites of living organisms and absorb nutrients from their host.

Most organisms use oxygen when they break down food and obtain energy through a process called respiration. An organism that uses oxygen for respiration is called an **aerobe** (AY rohb). You are an aerobic organism and so are most bacteria. In contrast, an organism that is adapted to live without oxygen is called an **anaerobe** (AN uh rohb). Several kinds of anaerobic bacteria live in the intestinal tract of humans. Some bacteria cannot survive in areas with oxygen.

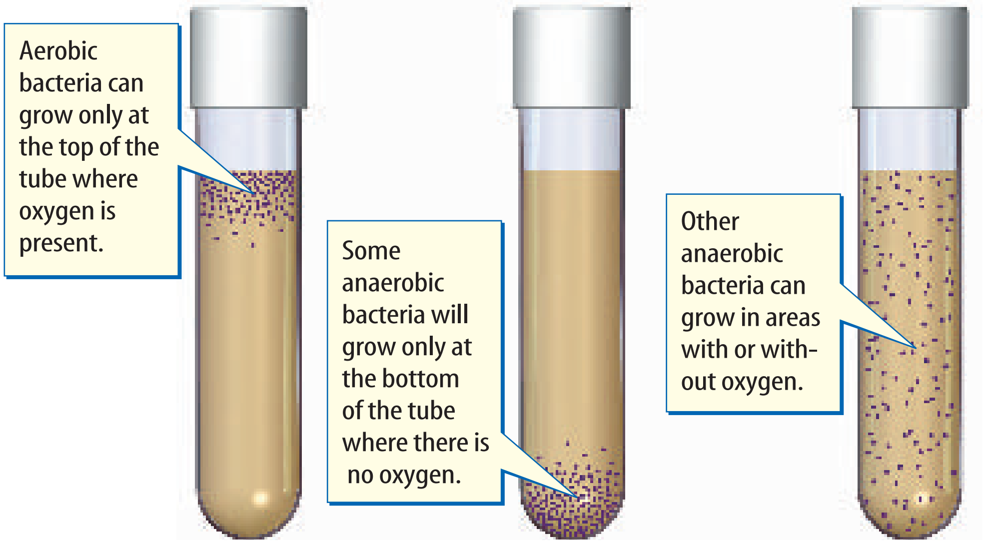
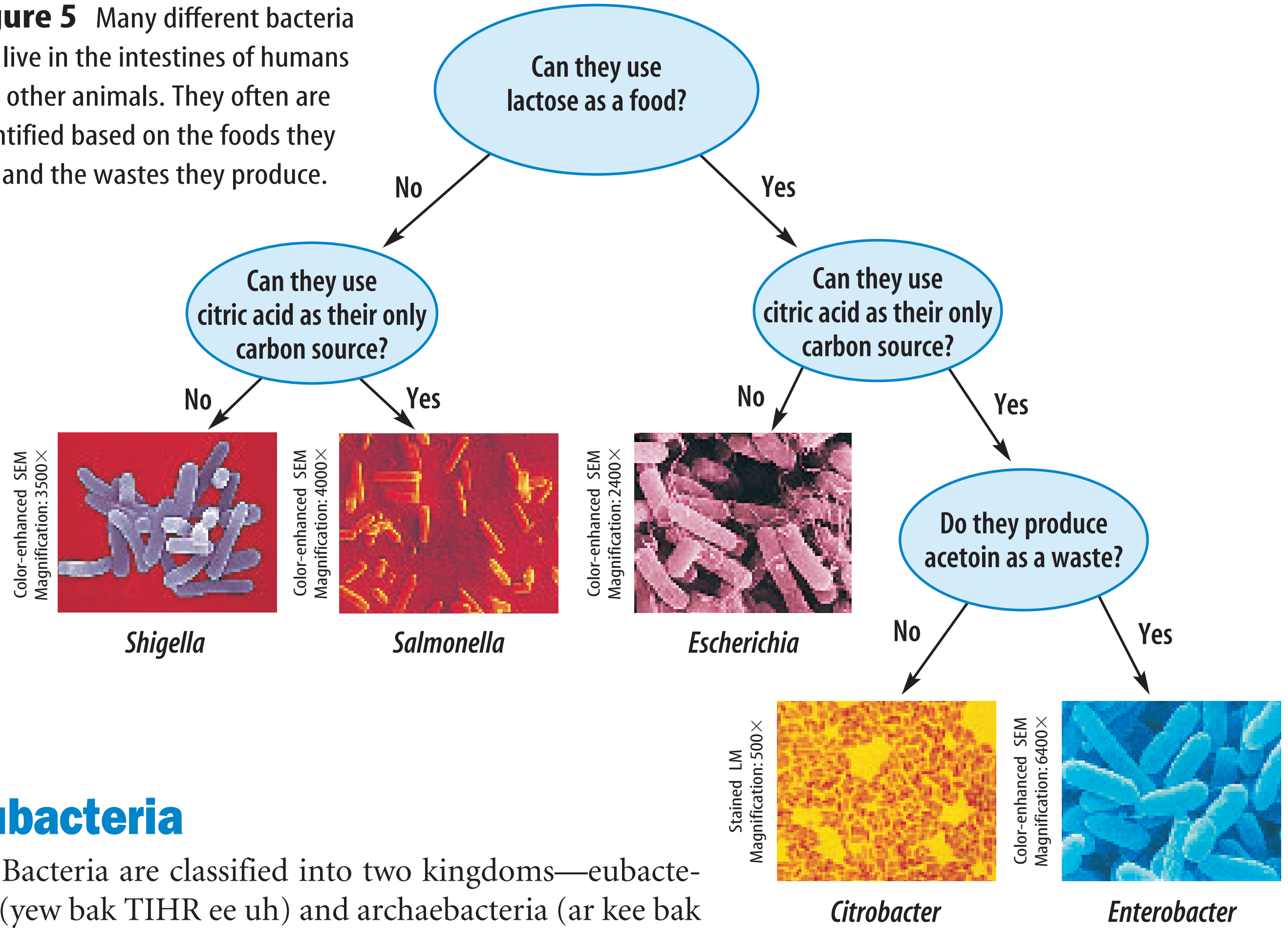


Figure 4 Observing where bacteria can grow in tubes of a nutrient mixture shows you how oxygen affects different types of bacteria.

Dr. L. Caro/Science Photo Library/Photo Researchers

Figure 5 Many different bacteria can live in the intestines of humans and other animals. They often are identified based on the foods they use and the wastes they produce.



Eubacteria

Bacteria are classified into two kingdoms—eubacteria (yew bak TIHR ee uh) and archaebacteria (ar kee bak TIHR ee uh). Eubacteria is the larger of the two kingdoms. Scientists must study many characteristics in order to classify eubacteria into smaller groups. Most eubacteria are grouped according to their cell shape and structure, the way they obtain food, the type of food they consume, and the wastes they produce, as shown in **Figure 5.** Other characteristics used to group eubacteria include the method used for cell movement and whether the organism is an aerobe or anaerobe. New information about their genetic material is changing how scientists classify this kingdom.

Producer Eubacteria One important group of producer eubacteria is the cyanobacteria (si an oh bak TIHR ee uh). They make their own food using carbon dioxide, water, and energy from sunlight. They also produce oxygen as a waste. Cyanobacteria contain chlorophyll and another pigment that is blue. This pigment combination gives cyanobacteria their common name—blue-green bacteria. However, some cyanobacteria are yellow, black, or red. The Red Sea gets its name from red cyanobacteria.

Reading Check *Why are cyanobacteria classified as producers?*

Science Online

Topic: Producer Eubacteria
Visit bookb.msscience.com for Web links to information about the ways that producer bacteria make food.

Activity Construct a food web that illustrates a community that relies on producer bacteria as a source of energy.

(l to r)Dr. Dennis Kunkel/Phot... NY... ...essel/G. Shih/Visuals Unlimited, Ann Siegleman/Visuals Unlimited, SCIMAT/Photo Researchers

Figure 6 These colonies of the cyanobacteria *Oscillatoria* can move by twisting like a screw.

Importance of Cyanobacteria Some cyanobacteria live together in long chains or filaments, as shown in **Figure 6.** Many are covered with a gelatinlike substance. This adaptation enables cyanobacteria to live in groups called colonies. They are an important source of food for some organisms in lakes, ponds, and oceans. The oxygen produced by cyanobacteria is used by other aquatic organisms.

Cyanobacteria also can cause problems for aquatic life. Have you ever seen a pond covered with smelly, green, bubbly slime? When large amounts of nutrients enter a pond, cyanobacteria increase in number. Eventually the population grows so large that a bloom is produced. A bloom looks like a mat of bubbly green slime on the surface of the water. Available resources in the water are used up quickly and the cyanobacteria die. Other bacteria that are aerobic consumers feed on dead cyanobacteria and use up the oxygen in the water. As a result of the reduced oxygen in the water, fish and other organisms die.

INTEGRATE Earth Science

Ocean Vents Geysers on the floor of the ocean are called ocean vents. Research to find out how ocean vents form and what conditions are like at an ocean vent. In your Science Journal, describe organisms that have been found living around ocean vents.

Consumer Eubacteria Most consumer eubacteria are grouped into one of two categories based on the results of the Gram's stain. These results can be seen under a microscope after the bacteria are treated with certain chemicals that are called stains. As shown in **Figure 7,** gram-positive cells stain purple because they have thicker cell walls. Gram-negative cells stain pink because they have thinner cell walls.

The composition of the cell wall also can affect how a bacterium is affected by medicines given to treat an infection. Some antibiotics (an ti bi AH tihks) will be more effective against gram-negative bacteria than they will be against gram-positive bacteria.

One group of eubacteria is unique because they do not produce cell walls. This allows them to change their shape. They are not described as coccus, bacillus, or spirillum. One type of bacteria in this group, *Mycoplasma pneumoniae,* causes a type of pneumonia in humans.

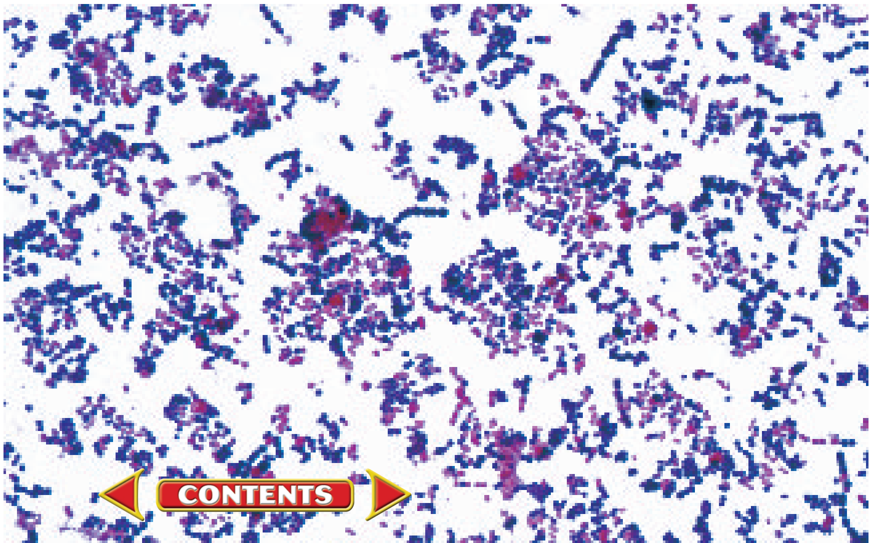


Figure 7 When stained with certain chemicals, bacteria with thin cell walls appear pink when viewed under a microscope. Those with thicker walls appear purple.

(t)T.E. Adams/Visuals Unlimited, (b)Frederick Skavara/Visuals Unlimited

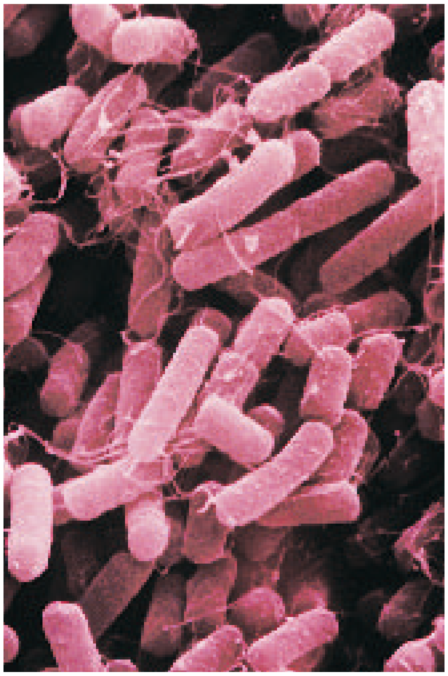
Archaebacteria

Kingdom Archaebacteria contains certain kinds of bacteria that often are found in extreme conditions, such as hot springs. The conditions in which some archaebacteria live today are similar to conditions found on Earth during its early history. Archaebacteria are divided into groups based on where they live or how they get energy.

Salt-, Heat-, and Acid-Lovers One group of archaebacteria lives in salty environments such as the Great Salt Lake in Utah and the Dead Sea. Some of them require a habitat ten times saltier than seawater to grow.

Other groups of archaebacteria include those that live in acidic or hot environments. Some of these bacteria live near deep ocean vents or in hot springs where the temperature of the water is above 100°C.

Methane Producers Bacteria in this group of archaebacteria are anaerobic. They live in muddy swamps, the intestines of cattle, and even in you. Methane producers, as shown in **Figure 8,** use carbon dioxide for energy and release methane gas as a waste. Sometimes methane produced by these bacteria bubbles up out of swamps and marshes. These archaebacteria also are used in the process of sewage treatment. In an oxygen-free tank, the bacteria are used to break down the waste material that has been filtered from sewage water.



Color-enhanced SEM Magnification: 6000×

Figure 8 Some methane-producing bacteria live in the digestive tracts of cattle. They help digest the plants that cattle eat.

section 1 review

Summary

Characteristics of Bacteria

- Bacteria live almost everywhere and usually are one of three basic shapes.
- A bacterium lacks a nucleus, most bacteria reproduce asexually, and they can be aerobes or anaerobes.

Eubacteria

- Eubacteria are grouped by cell shape and structure, how they obtain food, and whether they are gram-positive or gram-negative.

Archaebacteria

- Archaebacteria can be found in extreme environments.
- Some break down sewage and produce methane.

Self Check

1. **List** three shapes of bacteria cells.
2. **Compare and contrast** aerobic organisms and anaerobic organisms.
3. **Explain** how most bacteria reproduce.
4. **Identify** who is given credit for first discovering bacteria.
5. **Think Critically** A pond is surrounded by recently fertilized farm fields. What effect would rainwater runoff from the fields have on the organisms in the pond?

Applying Math

6. **Solve One-Step Equations** Some bacteria reproduce every 20 min. Suppose that you have one bacterium. How long would it take for the number of bacteria to increase to more than 1 million?

R. Kessel/G. Shih/Visuals Unlimited

LAB

Observing Cyanobacteria

You can obtain many species of cyanobacteria from ponds. When you look at these organisms under a microscope, you will find that they have similarities and differences. In this lab, compare and contrast species of cyanobacteria.

Real-World Question

What do cyanobacteria look like?

Goals

- **Observe** several species of cyanobacteria.
- **Describe** the structure and function of cyanobacteria.

Materials

micrograph photos of *Oscillatoria* and *Nostoc*
prepared slides of Oscillatoria *and* Nostoc
prepared slides of *Gloeocapsa* and *Anabaena*
micrograph photos of Anabaena *and* Gloeocapsa
microscope
*Alternate materials

Safety Precautions

Procedure

1. Copy the data table in your Science Journal. As you observe each cyanobacterium, record the presence or absence of each characteristic in the data table.
2. **Observe** prepared slides of *Gloeocapsa* and *Anabaena* under low and high power of the microscope. Notice the difference in the arrangement of the cells. In your Science Journal, draw and label a few cells of each.
3. **Observe** photos of *Nostoc* and *Oscillatoria.* In your Science Journal, draw and label a few cells of each.

Conclude and Apply

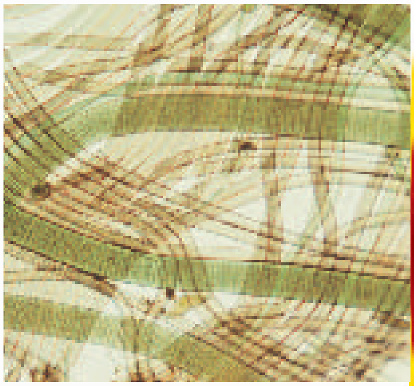
1. **Infer** what the color of each cyanobacterium means.
2. **Explain** how you can tell by observing that a cyanobacterium is a eubacterium.

Communicating Your Data

Compare your data table with those of other students in your class. **For more help, refer to the Science Skill Handbook.**

Cyanobacteria Observations

Structure	*Anabaena*	*Gloeocapsa*	*Nostoc*	*Oscillatoria*
Filament or colony		Do not write in this book.		
Nucleus				
Chlorophyll				
Gel-like layer				



T.E. Adams/Visuals Unlimited

section 2

Bacteria in Your Life

Beneficial Bacteria

When you hear the word *bacteria,* you probably associate it with sore throats or other illnesses. However, few bacteria cause illness. Most are important for other reasons. The benefits of most bacteria far outweigh the harmful effects of a few.

Bacteria That Help You Without bacteria, you would not be healthy for long. Bacteria, like those in **Figure 9,** are found inside your digestive system. These bacteria are found in particularly high numbers in your large intestine. Most are harmless to you, and they help you stay healthy. For example, some bacteria in your intestines are responsible for producing vitamin K, which is necessary for normal blood clot formation.

Some bacteria produce chemicals called **antibiotics** that limit the growth of other bacteria. For example, one type of bacteria that is commonly found living in soil produces the antibiotic streptomycin. Another kind of bacteria, *Bacillus,* produces the antibiotic found in many nonprescription antiseptic ointments. Many bacterial diseases in humans and animals can be treated with antibiotics.

as you read

What You'll Learn

- **Identify** some ways bacteria are helpful.
- **Determine** the importance of nitrogen-fixing bacteria.
- **Explain** how some bacteria can cause human disease.

Why It's Important

Discovering the ways bacteria affect your life can help you understand biological processes.

Review Vocabulary

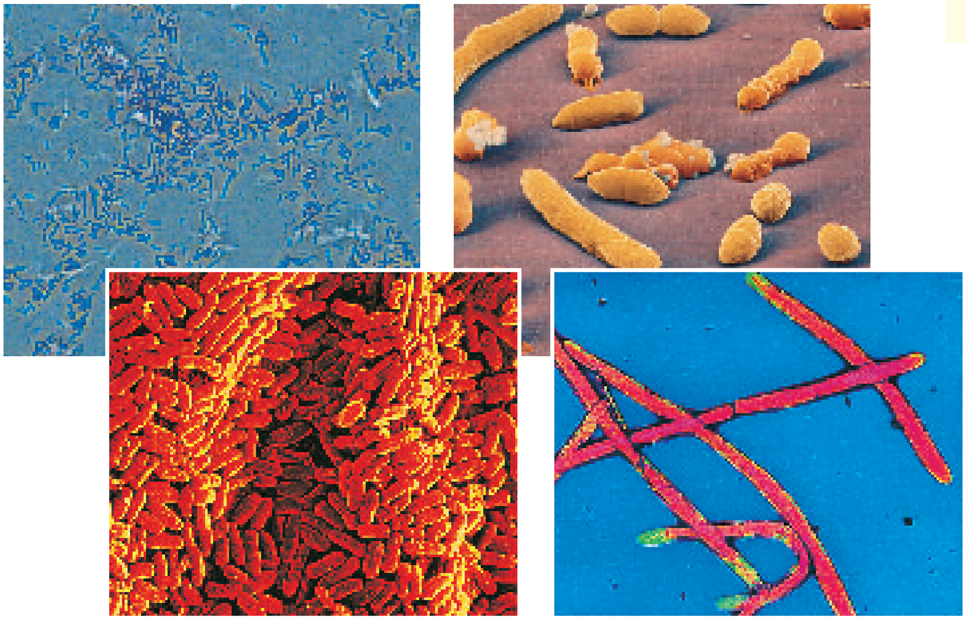
disease: a condition with symptoms that interferes with normal body functions

New Vocabulary

- antibiotic
- saprophyte
- nitrogen-fixing bacteria
- pathogen
- toxin
- endospore
- vaccine

Lactobacillus LM Magnification: 250×

Klebsiella Color-enhanced TEM Magnification: 11000×



E. coli Color-enhanced SEM Magnification: 3200×

Fusobacterium Color-enhanced TEM Magnification: 3000×

Figure 9 Many types of bacteria live naturally in your large intestine. They help you digest food and produce essential vitamins.

(tl)M. Abbey Photo/Photo Researchers, (tr)Oliver Meckes/ ... f S ... Lov ... iversity of Ulster/Stone/Getty Images, (br)A.B. Dowsett/Science Photo Library/Photo Researchers

Figure 10 Air is bubbled through the sewage in this aeration tank so that bacteria can break down much of the sewage wastes. **Determine** *whether the bacteria that live in this tank are aerobes or anaerobes.*

Ray Pfortner/Peter Arnold, Inc.

Bacteria and the Environment Without bacteria, there would be layers of dead material all over Earth deeper than you are tall. Consumer bacteria called saprophytes (SAP ruh fites) help maintain nature's balance. A **saprophyte** is any organism that uses dead organisms as food and energy sources. Saprophytic bacteria help recycle nutrients. These nutrients become available for use by other organisms. As shown in **Figure 10,** most sewage-treatment plants use saprophytic aerobic bacteria to break down wastes into carbon dioxide and water.

Reading Check *What is a saprophyte?*

Plants and animals must take in nitrogen to make needed proteins and nucleic acids. Animals can eat plants or other animals that contain nitrogen, but plants need to take nitrogen from the soil or air. Although air is about 78 percent nitrogen, neither animals nor plants can use it directly. **Nitrogen-fixing bacteria** change nitrogen from the air into forms that plants and animals can use. The roots of some plants such as peanuts and peas develop structures called nodules that contain nitrogen-fixing bacteria, as shown in **Figure 11.** It is estimated that nitrogen-fixing bacteria save U.S. farmers millions of dollars in fertilizer costs every year. Many of the cyanobacteria also can fix nitrogen and are important in providing nitrogen in usable forms to aquatic organisms.

Bioremediation Using organisms to help clean up or remove environmental pollutants is called bioremediation. One type of bioremediation uses bacteria to break down wastes and pollutants into simpler harmless compounds. Other bacteria use certain pollutants as a food source. Every year about five percent to ten percent of all wastes produced by industry, agriculture, and cities are treated by bioremediation. Sometimes bioremediation is used at the site where chemicals, such as oil, have been spilled. Research continues on ways to make bioremediation a faster process.

Mini LAB

Observing Bacterial Growth

Procedure

1. Obtain two or three **dried beans.**
2. Carefully break them into halves and place the halves into 10 mL of **distilled water** in a **glass beaker.**
3. Observe how many days it takes for the water to become cloudy and develop an unpleasant odor.

Analysis

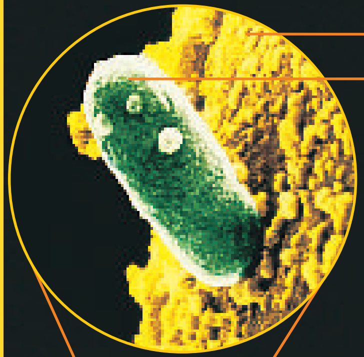
1. How long did it take for the water to become cloudy?
2. What do you think the bacteria were using as a food source?

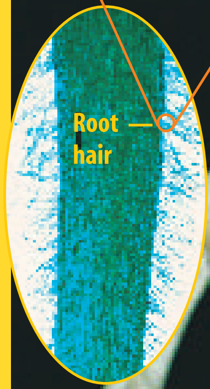
NATIONAL GEOGRAPHIC

VISUALIZING NITROGEN-FIXING BACTERIA

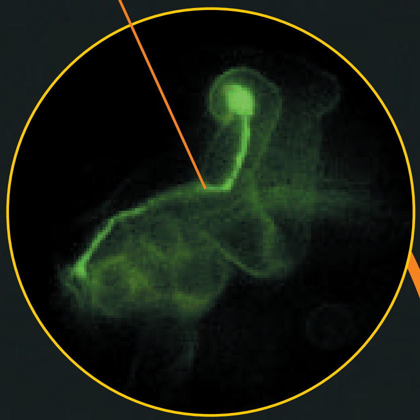
Figure 11

Although 78 percent of Earth's atmosphere is nitrogen gas (N_2), most living things are unable to use nitrogen in this form. Some bacteria, however, convert N_2 into the ammonium ion (NH_4^+) that organisms can use. This process is called nitrogen fixation. Nitrogen-fixing bacteria in soil can enter the roots of plants, such as beans, peanuts, alfalfa, and peas, as shown in the background photo. The bacteria and the plant form a relationship that benefits both of them.

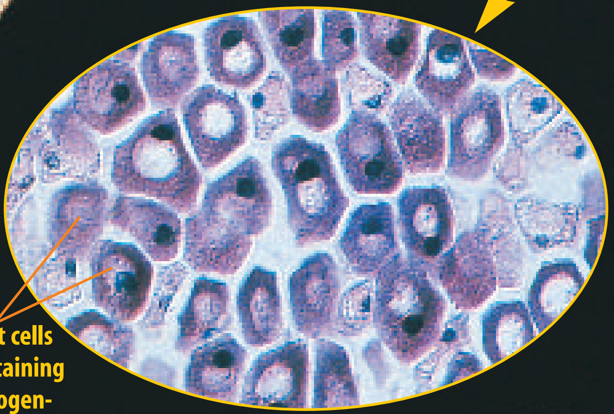




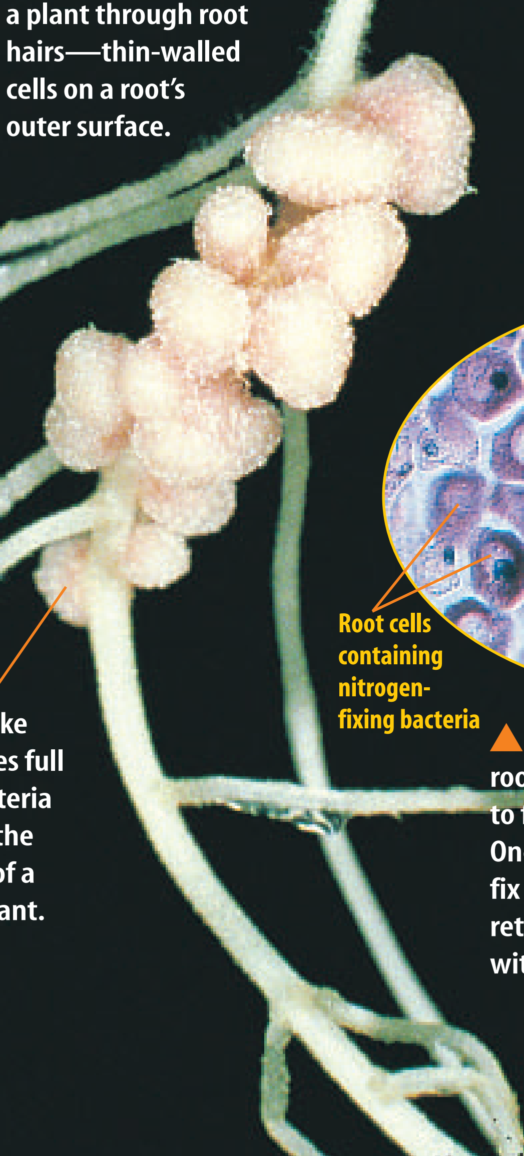
◀ Nitrogen-fixing bacteria typically enter a plant through root hairs—thin-walled cells on a root's outer surface.



▲ Once inside the root hair, the bacteria enlarge and cause the plant to produce a sort of tube called an infection thread. The bacteria move through the thread to reach cells deeper inside the root.



▲ The bacteria rapidly divide in the root cells, which in turn divide repeatedly to form tumorlike nodules on the roots. Once established, the bacteria (purple) fix nitrogen for use by the host plant. In return, the plant supplies the bacteria with sugars and other vital nutrients.



Beadlike nodules full of bacteria cover the roots of a pea plant.

(bkgd., tl)Jeremy Burgess/Science Photo Library/Photo Researchers ... Visuals Unlimited, (br)Astrid & Hanns-Frieder Michler/Science Photo Library/Photo Researchers

INTEGRATE Social Studies

Bioreactor Landfills As Earth's population grows and produces more waste, traditional landfills, which take 30 to 100 years to decompose waste, no longer fulfill the need for solid-waste disposal. Bioreactor landfills, which take 5 to 10 years to decompose waste, are beginning to be used instead. Bioreactor landfills can use aerobic or anaerobic bacteria, or a combination of the two, for rapid degradation of wastes.

Bacteria and Food Have you had any bacteria for lunch lately? Even before people understood that bacteria were involved, they were used in the production of foods. One of the first uses of bacteria was for making yogurt, a milk-based food that has been made in Europe and Asia for hundreds of years. Bacteria break down substances in milk to make many dairy products. Cheeses and buttermilk also can be produced with the aid of bacteria. Cheese making is shown in **Figure 12.**

Other foods you might have eaten also are made using bacteria. Sauerkraut, for example, is made with cabbage and a bacterial culture. Vinegar, pickles, olives, and soy sauce also are produced with the help of bacteria.

Bacteria in Industry Many industries rely on bacteria to make many products. Bacteria are grown in large containers called bioreactors. Conditions inside bioreactors are carefully controlled and monitored to allow for the growth of the bacteria. Medicines, enzymes, cleansers, and adhesives are some of the products that are made using bacteria.

Methane gas that is released as a waste by certain bacteria can be used as a fuel for heating, cooking, and industry. In landfills, methane-producing bacteria break down plant and animal material. The quantity of methane gas released by these bacteria is so large that some cities collect and burn it, as shown in **Figure 13.** Using bacteria to digest wastes and then produce methane gas could supply large amounts of fuel worldwide.

Reading Check *What waste gas produced by some bacteria can be used as a fuel?*

Figure 12 When bacteria such as *Streptococcus lactis* are added to milk, it causes the milk to separate into curds (solids) and whey (liquids). Other bacteria are added to the curds, which ripen into cheese. The type of cheese made depends on the bacterial species added to the curds.

Curds and whey

Curds

(l)Paul Almasy/CORBIS, (r)Joe Munroe/Photo Researchers

Figure 13 Methane gas produced by bacteria in this landfill is burning at the top of these collection tubes.

Harmful Bacteria

Not all bacteria are beneficial. Some bacteria are known as pathogens. A **pathogen** is any organism that causes disease. If you have ever had strep throat, you have had firsthand experience with a bacterial pathogen. Other pathogenic bacteria cause diphtheria, tetanus, and whooping cough in humans, as well as anthrax in humans and livestock.

How Pathogens Make You Sick Bacterial pathogens can cause illness and disease by several different methods. They can enter your body through a cut in the skin, you can inhale them, or they can enter in other ways. Once inside your body, they can multiply, damage normal cells, and cause illness and disease.

Some bacterial pathogens produce poisonous substances known as **toxins.** Botulism—a type of food poisoning that can result in paralysis and death—is caused by a toxin-producing bacterium. Botulism-causing bacteria are able to grow and produce toxins inside sealed cans of food. However, when growing conditions are unfavorable for their survival, some bacteria, like those that cause botulism, can produce thick-walled structures called **endospores.** Endospores, shown in **Figure 14,** can exist for hundreds of years before they resume growth. If the endospores of the botulism-causing bacteria are in canned food, they can grow and develop into regular bacterial cells and produce toxins again. Commercially canned foods undergo a process that uses steam under high pressure, which kills bacteria and most endospores.

Science Online

Topic: Pathogens

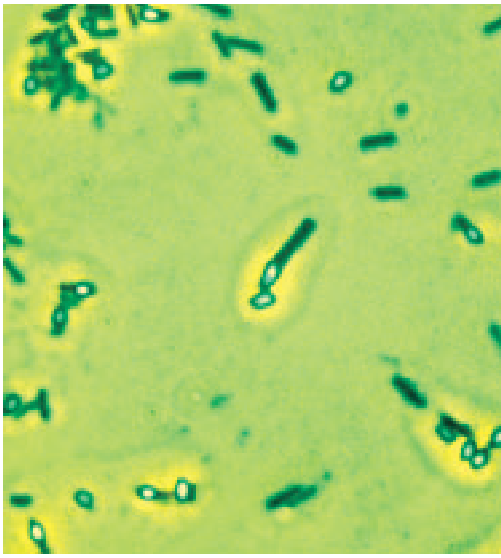
Visit bookb.msscience.com for Web links to information about pathogenic bacteria and antibiotics.

Activity Compile a list of common antibiotics and the bacterial pathogens they are used to treat.

Figure 14 Bacterial endospores can survive harsh winters, dry conditions, and heat.

Describe *possible ways endospores can be destroyed.*

LM Magnification: 600×



(t)Terry Wild Studio, (b)George Wilder/Visuals Unlimited

Figure 15 Pasteurization lowers the amount of bacteria in foods. Products, such as juice, ice cream, and yogurt, are pasteurized.

Pasteurization Unless it has been sterilized, all food contains bacteria. But heating food to sterilizing temperatures can change its taste. Pasteurization is a process of heating food to a temperature that kills most harmful bacteria but causes little change to the taste of the food. You are probably most familiar with pasteurized milk, but some fruit juices and other foods, as shown in **Figure 15,** also are pasteurized.

Applying Science

Controlling Bacterial Growth

Bacteria can be controlled by slowing or preventing their growth, or killing them. When trying to control bacteria that affect humans, it is often desirable just to slow their growth because substances that kill bacteria or prevent them from growing can harm humans. For example, bleach often is used to kill bacteria in bathrooms or on kitchen surfaces, but it is poisonous if swallowed. *Antiseptic* is the word used to describe substances that slow the growth of bacteria.

Identifying the Problem

Advertisers often claim that a substance kills bacteria, when in fact the substance only slows its growth. Many mouthwash advertisements make this claim. How could you test three mouthwashes to see which one is the best antiseptic?

Solving the Problem

1. Describe an experiment that you could do that would test which of three mouthwash products is the most effective antiseptic.
2. Identify the control in your experiment.
3. Read the ingredients labels on bottles of mouthwash. List the ingredients in the mouthwash. What ingredient do you think is the antiseptic? Explain.

Amanita Pictures

Figure 16 Each of these paper disks contains a different antibiotic. Clear areas where no bacteria are growing can be seen around four of the disks.
Infer *which one of these disks contains an antibiotic that is most effective against the bacteria growing on the plate.*

INTEGRATE Health

Treating Bacterial Diseases

Bacterial diseases in humans and animals usually are treated effectively with antibiotics. Penicillin, a well-known antibiotic, works by preventing bacteria from making cell walls. Without cell walls, certain bacteria cannot survive. **Figure 16** shows antibiotics at work.

Vaccines can prevent some bacterial diseases. A **vaccine** can be made from damaged particles taken from bacterial cell walls or from killed bacteria. Once the vaccine is injected, white blood cells in the blood recognize that type of bacteria. If the same type of bacteria enters the body at a later time, the white blood cells immediately attack them. Vaccines have been produced that are effective against many bacterial diseases.

section 2 review

Summary

Beneficial Bacteria

- Many types of bacteria help you stay healthy.
- Antibiotics are produced by some bacteria.
- Bacteria decompose dead material.
- Certain bacteria change nitrogen in the air to forms that other organisms can use.
- Some bacteria are used to remove pollutants.
- Bacteria help to produce some foods.

Harmful Bacteria

- Some bacteria cause disease.
- Some bacteria have endospores that enable them to adapt to harsh environments.

Self Check

1. **Explain** why saprophytic bacteria are helpful.
2. **Summarize** how nitrogen-fixing bacteria benefit plants and animals.
3. **List** three uses of bacteria in food production and other industry.
4. **Describe** how some bacteria cause disease.
5. **Think Critically** Why is botulism associated with canned foods and not fresh foods?

Applying Skills

6. **Measure in SI** Air can have more than 3,500 bacteria per cubic meter. How many bacteria might be in your classroom?

John Durham/Science Photo Library/Photo Researchers

LAB

Design Your Own

Composting

Goals

- **Predict** which of several items will decompose in a compost pile and which will not.
- **Demonstrate** the decomposition, or lack thereof, of several items.
- **Compare and contrast** the speed at which various items break down.

Possible Materials

widemouthed, clear-glass jars (at least 4)
soil
water
watering can
banana peel
apple core
scrap of newspaper
leaf
plastic candy wrapper
scrap of aluminum foil

Safety Precautions

Real-World Question

Over time, landfills fill up and new places to dump trash become more difficult to find. One way to reduce the amount of trash that must be dumped in a landfill is to recycle. Composting is a form of recycling that changes plant wastes into reusable, nutrient-rich compost. How do plant wastes become compost? What types of organisms can assist in the process? What types of items can be composted and what types cannot?

Form a Hypothesis

Based on readings or prior knowledge, form a hypothesis about what types of items will decompose in a compost pile and which will not.

(t)KS Studios, (b)John Evans

CONTENTS

Test Your Hypothesis

Make a Plan

1. **Decide** what items you are going to test. Choose some items that you think will decompose and some that you think will not.
2. **Predict** which of the items you chose will or will not decompose. Of the items that will, which do you think will decompose fastest? Slowest?
3. **Decide** how you will test whether or not the items decompose. How will you see the items? You may need to research composting in books, magazines, or on the Internet.
4. **Prepare** a data table in your Science Journal to record your observations.
5. **Identify** all constants, variables, and controls of the experiment.

Follow Your Plan

1. Make sure your teacher approves of your plan and your data table before you start.
2. **Observe** Set up your experiment and collect data as planned.
3. **Record Data** While doing the experiment, record your observations and complete your data tables in your Science Journal.

Analyze Your Data

1. **Describe** your results. Did all of the items decompose? If not, which did and which did not?
2. Were your predictions correct? Explain.
3. **Compare** how fast each item decomposed. Which items decomposed fastest and which took longer?

Conclude and Apply

1. What general statement(s) can you make about which items can be composted and which cannot? What about the speed of decomposition?
2. **Determine** whether your results support your hypothesis.
3. **Explain** what might happen to your compost pile if antibiotics were added to it.
4. **Describe** what you think happens in a landfill to items similar to those that you tested.

Communicating Your Data

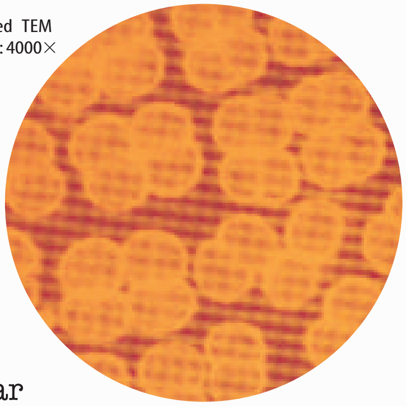
Point of View Write a letter to the editor of a local newspaper describing what you have learned about composting and encouraging more community composting.

SCIENCE Stats

Unusual Bacteria

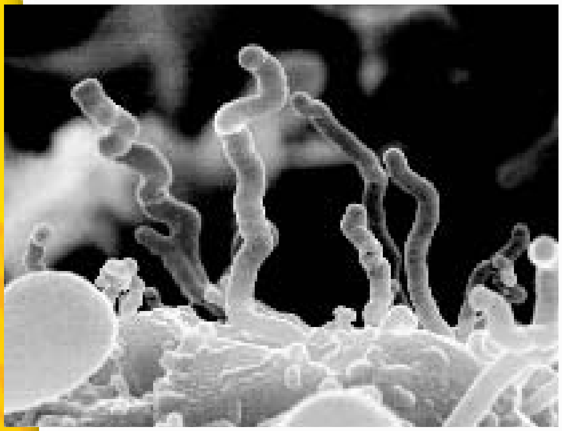
Did you know...

Color-enhanced TEM
Magnification: 4000×



D. radiodurans

...The hardiest bacteria, *Deinococcus radiodurans* (DE no KO kus·RA de oh DOOR anz), has a nasty odor, which has been described as similar to rotten cabbage. It might have an odor, but it can survive 3,000 times more radiation than humans because it quickly repairs damage to its DNA molecule. These bacteria were discovered in canned meat when they survived sterilization by radiation.



Nanobes

...The smallest bacteria, nanobes (NA nobes), are Earth's smallest living things. They have been found 5 km beneath the ocean floor near Australia. These tiny cells are 20 to 150 nanometers long. That means, depending on their size, it would take about 6,500,000 to 50,000,000 nanobes lined up to equal 1 m!

Applying Math What is the difference in size between the largest nanobe and the smallest nanobe?

...Earth's oldest living bacteria are thought to be 250 million years old. These ancient bacteria were revived from a crystal of rock salt buried 579 m below the desert floor in New Mexico.

Bacillus permians

Find Out About It

Do research about halophiles, the bacteria that can live in highly salty environments. What is the maximum salt concentration in which extreme halophiles can survive? How does this compare to the maximum salt concentration at which nonhalophilic bacteria can survive? Visit bookb.msscience.com/science_stats to learn more.

(t)P. Canumette/Visuals Unlimited, (c)Dr. Philippa Uwins, The University of Queenslan ...)Da ... r)R ... NewMedia Inc./CORBIS

Reviewing Main Ideas

Section 1 What are bacteria?

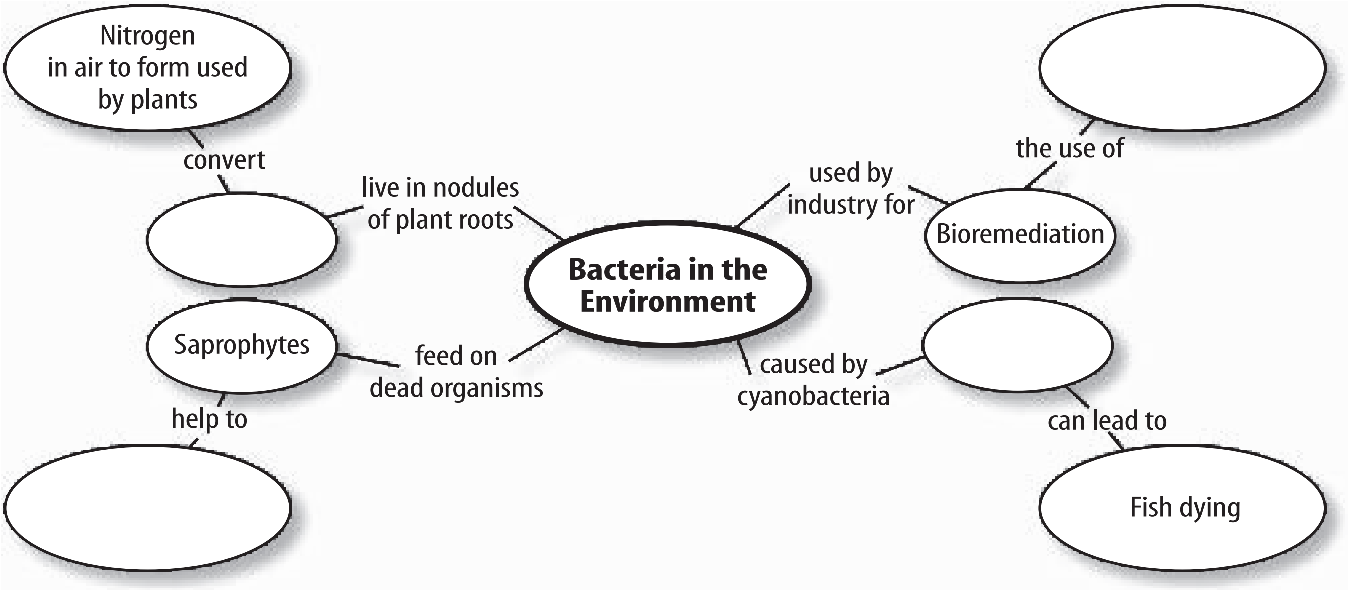
1. Bacteria can be found almost everywhere. They have one of three basic shapes—coccus, bacillus, or spirillum.
2. Bacteria are prokaryotic cells that usually reproduce by fission. All bacteria contain DNA, ribosomes, and cytoplasm but lack a membrane-bound nucleus.
3. Most bacteria are consumers, but some can make their own food. Anaeroic bacteria live without oxygen, but aerobic bacteria need oxygen to survive.
4. Cell shape and structure, how they get food, if they use oxygen, and their waste products can be used to classify eubacteria.
5. Cyanobacteria are producer eubacteria. They are an important source of food and oxygen for some aquatic organisms.
6. Archaebacteria are bacteria that often exist in extreme conditions, such as near ocean vents or in hot springs.

Section 2 Bacteria in Your Life

1. Most bacteria are helpful. They aid in recycling nutrients, fixing nitrogen, or helping in food production. They even can be used to break down pollutants.
2. Some bacteria that live in your body help you stay healthy and survive.
3. Other bacteria are harmful because they can cause disease in organisms.
4. Pasteurization can prevent the growth of harmful bacteria in food.

Visualizing Main Ideas

Copy and complete the following concept map on how bacteria affect the environment.



chapter 1 Review

Using Vocabulary

aerobe p. 10	nitrogen-fixing bacteria p. 16
anaerobe p. 10	pathogen p. 19
antibiotic p. 15	saprophyte p. 16
endospore p. 19	toxin p. 19
fission p. 10	vaccine p. 21
flagella p. 9	

Fill in the blanks with the correct word or words.

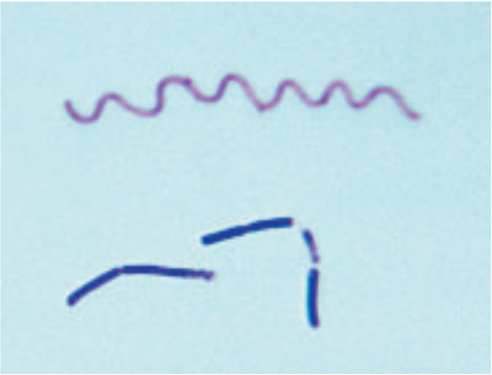
1. A(n) ________ uses dead organisms as a food source.
2. A(n) ________ can prevent some bacterial diseases.
3. A(n) ________ causes disease.
4. A bacterium that needs oxygen to carry out respiration is a(n) ________.
5. Bacteria reproduce using ________.
6. ________ are bacteria that convert nitrogen in the air to a form used by plants.
7. A(n) ________ can live without oxygen.

Checking Concepts

Choose the word or phrase that best answers the question.

8. What is a way of cleaning up an ecosystem using bacteria to break down harmful compounds?
   A) landfill C) toxic waste dumps
   B) waste storage D) bioremediation
9. What pigment do cyanobacteria need to make food?
   A) chlorophyll C) plasmids
   B) chromosomes D) ribosomes
10. Which of the following terms describes most bacteria?
   A) anaerobic C) many-celled
   B) pathogens D) beneficial
11. What is the name for rod-shaped bacteria?
   A) bacilli C) spirilla
   B) cocci D) colonies
12. What structure allows bacteria to stick to surfaces?
   A) capsule C) chromosome
   B) flagella D) cell wall
13. What organisms can grow as blooms in ponds?
   A) archaebacteria C) cocci
   B) cyanobacteria D) viruses
14. Which of these organisms are recyclers in the environment?
   A) producers C) saprophytes
   B) flagella D) pathogens
15. Which of the following is caused by a pathogenic bacterium?
   A) an antibiotic C) nitrogen fixation
   B) cheese D) strep throat

Use the photo below to answer questions 16 and 17.



16. What shape are the gram-positive bacteria in the above photograph?
   A) coccus C) spirillum
   B) bacillus D) ovoid
17. What shape are the gram-negative bacteria in the above photograph?
   A) coccus C) spirillum
   B) bacillus D) ovoid

Carolina Biological /Visuals Unlimited

Thinking Critically

18. Infer what would happen if nitrogen-fixing bacteria could no longer live on the roots of some plants.

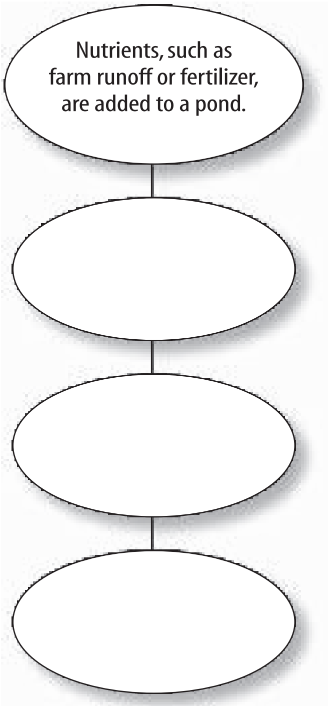
19. Explain why bacteria are capable of surviving in almost all environments of the world.

20. Draw a conclusion as to why farmers often rotate crops such as beans, peas, and peanuts with other crops such as corn, wheat, and cotton.

21. Describe One organism that causes bacterial pneumonia is called pneumococcus. What is its shape?

22. List the precautions that can be taken to prevent food poisoning.

23. Concept Map Copy and complete the following events-chain concept map about the events surrounding a cyanobacteria bloom.



24. Design an experiment to decide if a kind of bacteria could grow anaerobically.

25. Describe the nitrogen-fixing process in your own words, using numbered steps. You will probably have more than four steps.

26. Infer the shape of pneumococcus bacteria.

Performance Activities

27. Poster Create a poster that illustrates the effects of bacteria. Use photos from magazines and your own drawings.

28. Poem Write a poem that demonstrates your knowledge of the importance of bacteria to human health.

Applying Math

Use the table below to answer questions 29 and 30.

Bacterial Reproduction Rates

Temperature (°C)	Doubling Rate Per Hour
20.5	2.0
30.5	3.0
36.0	2.5
39.2	1.2

29. Doubling Rate Graph the data from the table above. Using the graph, determine where the doubling rate would be at 20°C. Where would the doubling rate be at 40°C?

30. Bacterial Reproduction Bacteria can reproduce rapidly. At 30.5°C, some species of bacteria can double their numbers in 3.0 hours. A biologist places a single bacterium on growth medium at 6:00 A.M. and incubates the bacteria until 4:00 P.M. the same afternoon. How many bacterium will there be?

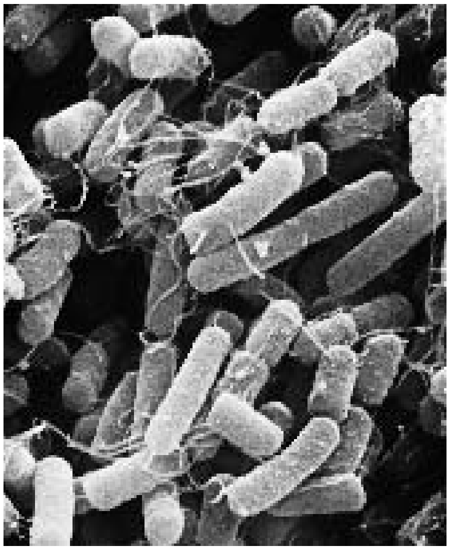
Part 1 Multiple Choice

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

1. Most pathogenic bacteria are consumer eubacteria and are grouped according to what characteristic?
   A. chlorophyll
   B. ribosomes
   C. cell wall
   D. plasmids

2. Which of the following cannot be found in a bacterial cell?
   A. ribosomes
   B. nucleus
   C. chromosome
   D. cytoplasm

Use the photo below to answer questions 3 and 4.

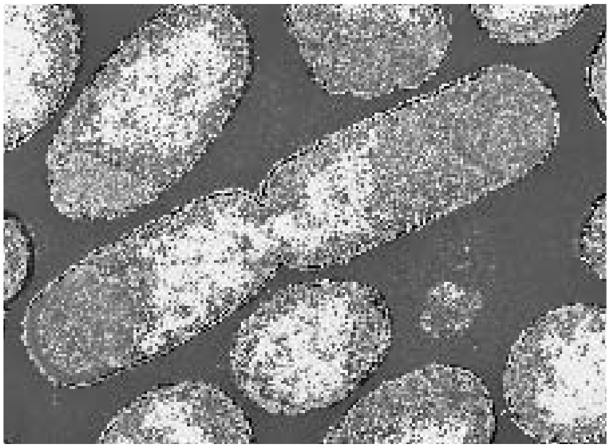


3. What shape are the bacterial cells shown above?
   A. bacillus
   B. coccus
   C. spirillum
   D. tubular

4. These bacteria are methane producers. Which of the following statements is true of these bacteria?
   A. They are aerobic.
   B. They are in Kingdom Eubacteria.
   C. They are used in sewage treatment.
   D. They live only near deep ocean vents.

5. Which of the following foods is not processed with the help of bacteria?
   A. beef
   B. cheese
   C. yogurt
   D. pickles

Use the photo below to answer questions 6 and 7.



6. What process is occurring in the above photograph?
   A. mitosis
   B. fission
   C. fusion
   D. conjugation

7. The above is an example of what kind of reproduction?
   A. sexual
   B. asexual
   C. meitotic
   D. symbiotic

8. What characteristic probably was used in naming cyanobacteria?
   A. pigments
   B. slime layer
   C. cell shape
   D. cell wall

9. Each bacterium has
   A. a nucleus.
   B. mitochondria.
   C. ribosomes.
   D. a capsule.

Test-Taking Tip

Listen and Read Listen carefully to the instructions from the teacher and read the directions and each question carefully.

(l)R. Kessel/G. Shih/Visuals Unlimited, (r)A. B. Dowsett/Science Photo Library/Photo Researchers

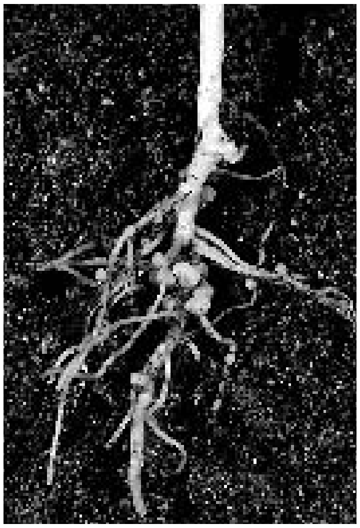
Part 2 Short Response/Grid In

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

10. What characteristics can be used in naming eubacteria?

11. What does an antiseptic do? Why would an antiseptic be dangerous to humans if it killed all bacteria?

Use the photo below to answer questions 12 and 13.



12. The figure above shows plant roots that have nodules, which contain nitrogen-fixing bacteria. How does this benefit the plant?

13. This symbiotic relationship is mutualistic. Explain how bacteria benefit from this relationship.

14. What happens to dead plant material that is plowed into the soil following a crop harvest? Why is this plowing beneficial to the quality of the soil?

15. What is bioremediation? Give an example of how it is used.

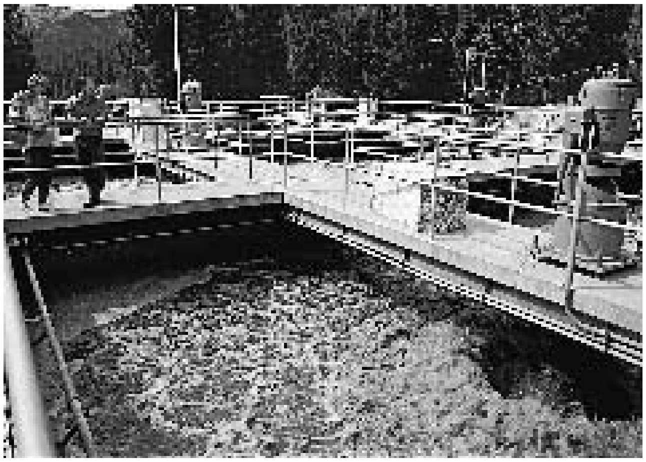
16. Most of the dairy products that you buy are pasteurized. What is pasteurization? How is it different from sterilization?

Part 3 Open Ended

Record your answers on a sheet of paper.

17. An antibiotic is prescribed to a patient to take for 10 days. After two days the patient feels better and stops taking the antibiotic. Several days later, the infection returns, but this time a greater amount of antibiotic was needed to cure the infection. Why? How could the patient have avoided the recurrence of the infection?

Use the photo below to answer questions 18 and 19.



18. Describe how aerobic bacteria in the wastewater treatment tank shown above clean the water. Where does the energy that was in the waste go?

19. Aerobic bacteria removed from the tanks, along with some solid waste, form sludge. After the sludge is dried, detoxified, and sterilized, it is either burned or applied to soil. What would be the benefit of applying it to soil? Why is it important to detoxify and sterilize the sludge first?

20. What causes a bloom of cyanobacteria? Explain how it can cause fish and other organisms in a pond to die.

(l)Breck P. Kent/Earth Scenes, (r)Ray Pfortner/Peter Arnold, Inc.

chapter 2

Protists and Fungi

chapter preview

sections

1 Protists

Lab *Comparing Algae and Protozoans*

2 Fungi

Lab *Creating a Fungus Field Guide*

Virtual Lab *How can microscopic protists and fungi be characterized?*

Fungi—Terrestrial Icebergs

A mushroom is like the tip of an iceberg; a small, visible portion of an extensive fungal network that grows under the soil. Many fungi and plant roots interact. These fungi help provide water and nutrients to these plants in exchange for carbohydrates that plants produce.

Science Journal What other ways might fungi benefit other organisms and the environment?

Steve Austin; Papilio/ CORBIS

Start-Up Activities

Launch LAB

Dissect a Mushroom

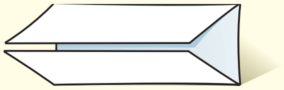
It is hard to tell by a mushroom's appearance whether it is safe to eat or is poisonous. Some edible mushrooms are so highly prized that people keep their location a secret for fear that others will find their treasure. Do the lab below to learn about the parts of mushrooms.

1. Obtain a mushroom from your teacher.
2. Using a magnifying lens, observe the underside of the mushroom cap. Then carefully pull off the cap and observe the gills, which are the thin, tissuelike structures. Hundreds of thousands of tiny reproductive structures called spores form on these gills.
3. Use your fingers or forceps to pull the stalk apart lengthwise. Continue this process until the pieces are as small as you can get them.
4. **Think Critically** In your Science Journal, write a description of the parts of the mushroom, and make a labeled drawing of the mushroom and its parts.

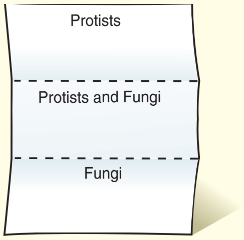
FOLDABLES™ Study Organizer

Compare Protists and Fungi Make the following Foldable to help you see how protists and fungi are similar and different.

STEP 1 **Fold** the top of a vertical piece of paper down and the bottom up to divide the paper into thirds.



STEP 2 **Unfold and label** the three sections as shown.



Read for Main Ideas As you read the chapter, write information about each type of organism in the appropriate section, and information that they share in the middle section.

Science Online — Preview this chapter's content and activities at bookb.msscience.com

Steve Austin; Papilio/ CORBIS

section 1

Protists

as you read

What You'll Learn

- **Describe** the characteristics shared by all protists.
- **Compare and contrast** the three groups of protists.
- **List** examples of each of the three protist groups.
- **Explain** why protists are so difficult to classify.

Why It's Important

Many protists are important food sources for other organisms.

Review Vocabulary

asexual reproduction: requires only one parent to produce a new genetically identical individual

New Vocabulary

- protist
- algae
- flagellum
- protozoan
- cilia
- pseudopod

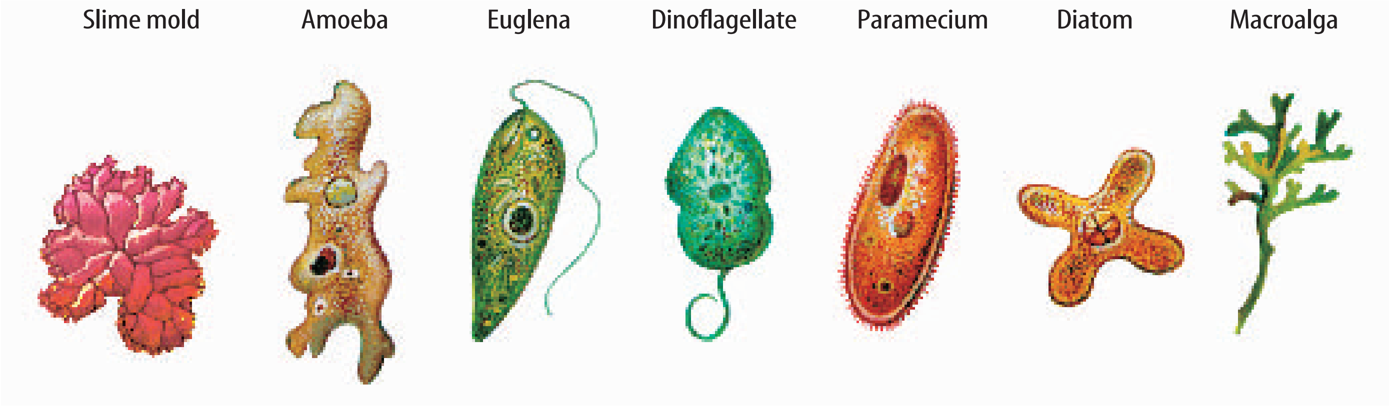
What is a protist?

Look at the organisms in **Figure 1.** As different as they appear, all of these organisms belong to one kingdom—the protist kingdom. A **protist** is a one- or many-celled organism that lives in moist or wet surroundings. All protists have eukaryotic cells—cells that have a nucleus and other internal, membrane-bound structures. Some protists are plantlike. They contain chlorophyll and make their own food. Other protists are animal-like. They do not have chlorophyll and can move. Some protists have a solid or a shell-like structure on the outside of their bodies.

Protist Reproduction Protists usually reproduce asexually by cell division. During cell division, the hereditary material in the nucleus is duplicated, the nucleus divides, and then the cytoplasm usually divides. The result is two new cells that are genetically identical. Asexual reproduction of many-celled protists occurs by regeneration. Parts of the organism can break off and grow into entirely new organisms that are genetically identical.

Most protists also can reproduce sexually. During sexual reproduction, the process of meiosis produces sex cells. Two sex cells join to form a new organism that is genetically different from the two organisms that were the sources of the sex cells. How and when sexual reproduction occurs depends on the specific type of protist.

Figure 1 The protist kingdom is made up of a variety of organisms.
Describe *the characteristics that the organisms below have in common.*



CONTENTS

Classification of Protists

Not all scientists agree about how to classify the organisms in this group. Protists usually are divided into three groups—plantlike, animal-like, and funguslike—based on whether they share certain characteristics with plants, animals, or fungi. **Table 1** shows some of these characteristics. As you read this section, you will understand some of the problems of grouping protists in this way.

Table 1 Characteristics of Protist Groups

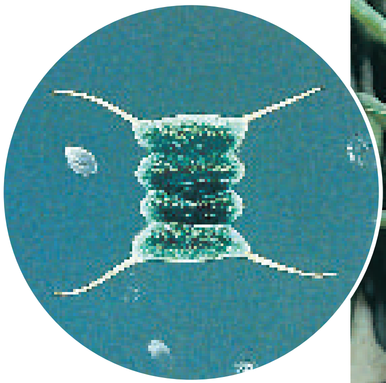
Plantlike	Animal-Like	Funguslike
Contain chlorophyll and make their own food using photosynthesis	Cannot make their own food; capture other organisms for food	Cannot make their own food; absorb food from their surroundings
Have cell walls	Do not have cell walls	Some organisms have cell walls; others do not
No specialized ways to move from place to place	Have specialized ways to move from place to place	Have specialized ways to move from place to place

Evolution of Protists Although protists that produce a hard outer covering have left many fossils, other protists lack hard parts, so few fossils of these organisms have been found. But, by studying the genetic material and structure of modern protists, scientists are beginning to understand how they are related to each other and to other organisms. Scientists hypothesize that the common ancestor of most protists was a one-celled organism with a nucleus and other cellular structures. However, evidence suggests that protists with the ability to make their own food could have had a different ancestor than protists that cannot make their own food.

Plantlike Protists

Protists in this group are called plantlike because, like plants, they contain the pigment chlorophyll in chloroplasts and can make their own food. Many of them have cell walls like plants, and some have structures that hold them in place just as the roots of a plant do, but these protists do not have roots.

Plantlike protists are known as **algae** (AL jee) (singular, *alga*). As shown in **Figure 2,** some are one cell and others have many cells. Even though all algae have chlorophyll, not all of them look green. Many have other pigments that cover up their chlorophyll.

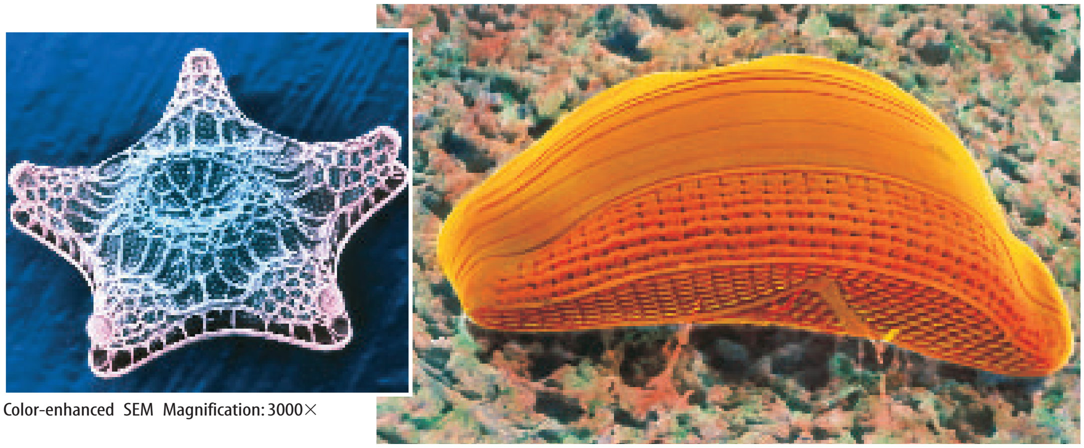


Color-enhanced SEM
Magnification: 3100×

Figure 2 Algae exist in many shapes and sizes. Microscopic algae (left photo) are found in freshwater and salt water. You can see some types of green algae growing on rocks, washed up on the beach, or floating in the water.

(l)Jean Claude Revy/PhotoTake, NYC, (r)Anne Hubbard/Photo Researchers

Figure 3 The cell walls of diatoms contain silica, the main element in glass. The body of a diatom is like a small box with a lid. The pattern of dots, pits, and lines on the cell wall's surface is different for each species of diatom.



Color-enhanced SEM Magnification: 3000×

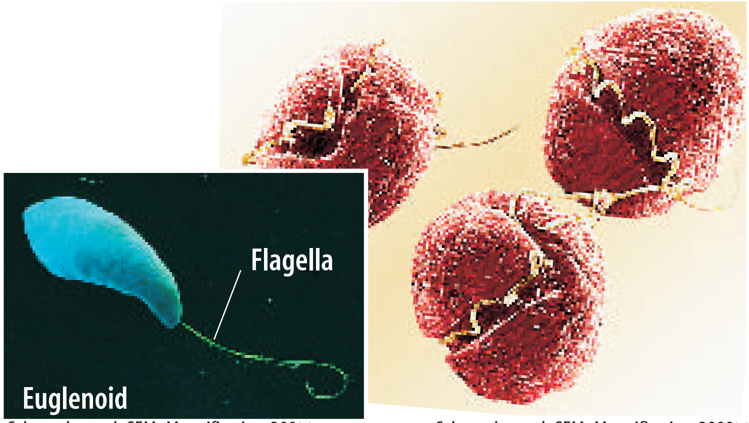
Color-enhanced SEM Magnification: 2866×

Diatoms Extremely large populations of diatoms exist. Diatoms, shown in **Figure 3,** are found in freshwater and salt water. They have a golden-brown pigment that covers up the green chlorophyll. Diatoms secrete glasslike boxes around themselves. When the organisms die, these boxes sink. Over thousands of years, they can collect and form deep layers.

Dinoflagellates Another group of algae is called the dinoflagellates, which means "spinning flagellates." Dinoflagellates, as shown in **Figure 4,** have two flagella. A **flagellum** (plural, *flagella*) is a long, thin, whiplike structure used for movement. One flagellum circles the cell like a belt, and another is attached to one end like a tail. As the two flagella move, they cause the cell to spin. Because many of the species in this group produce a chemical that causes them to glow at night, they are known as fire algae. Almost all dinoflagellates live in salt water. While most contain chlorophyll, some do not and must feed on other organisms.

Figure 4 Most dinoflagellates live in the sea. Some are free living and others are parasites. Still others, like the *Spiniferites* cyst (right photo), can produce toxins that make other organisms sick.
Determine *how euglenoids are similar to plants and animals.*

Euglenoids Protists that have characteristics of both plants and animals are known as the euglenoids (yoo GLEE noydz). Many of these one-celled algae have chloroplasts, but some do not. Those with chloroplasts, like *Euglena* shown in **Figure 4,** can produce their own food. However, when light is not present, *Euglena* can feed on bacteria and other protists. Although *Euglena* has no cell wall, it does have a strong, flexible layer inside the cell membrane that helps it move and change shape. Many euglenoids move by whipping their flagella. An eyespot, an adaptation that is sensitive to light, helps photosynthetic euglenoids move toward light.



Color-enhanced SEM Magnification: 300×

Color-enhanced SEM Magnification: 3000×

(tl)NHMPL/Stone/Getty Images, (tr)Microfield Scienctific Ltd/Science Photo Library/Photo Rese… …)Dr. David Phillips/Visuals Unlimited

(l)Pat & Tom Leeson/Photo Researchers, (r)Jeffrey L. Rotman/Peter Arnold, Inc.

Red Algae Most red algae are many-celled and, along with the many-celled brown and green algae, sometimes are called seaweeds. Red algae contain chlorophyll, but they also produce large amounts of a red pigment. Some species of red algae can live up to 200 m deep in the ocean. They can absorb the limited amount of light at those depths to carry out the process of photosynthesis. **Figure 5** shows the depths at which different types of algae can live.

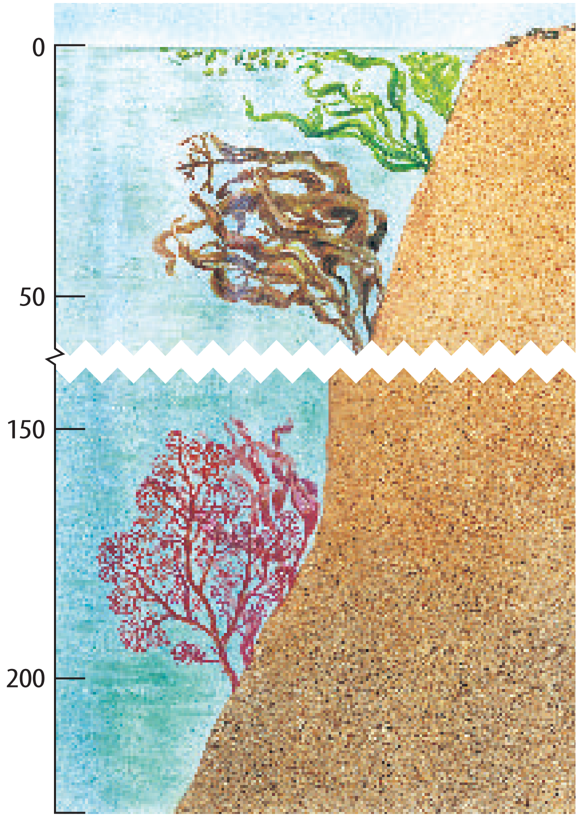


Figure 5 Green algae are found closer to the surface. Brown algae can grow from a depth of about 35 m. Red algae are found in the deepest water at 175 m to 200 m.

Green Algae There are more than 7,000 species of green algae in this diverse group of organisms. These algae, like the one shown in **Figure 6,** contain large amounts of chlorophyll. Green algae can be one-celled or many-celled. They are the most plant-like of all the algae. Because plants and green algae are similar in their structure, chlorophyll, and how they undergo photosynthesis, some scientists hypothesize that plants evolved from ancient, many-celled green algae. Although most green algae live in water, you can observe types that live in other moist environments, including on damp tree trunks and wet sidewalks.

Brown Algae As you might expect from their name, brown algae contain a brown pigment in addition to chlorophyll. They usually are found growing in cool, saltwater environments. Brown algae are many-celled and vary greatly in size. An important food source for many fish and invertebrates is a brown alga called kelp. Kelp, shown in **Figure 6,** forms a dense mat of stalks and leaflike blades where small fish and other animals live. Giant kelp is the largest organism in the protist kingdom and can grow to be 100 m in length.

Reading Check *What is kelp?*

Figure 6 Green algae (left photo) often can be seen on the surface of ponds in the summer. Giant kelp, a brown alga, can form forests like this one located off the coast of California. Extracts from kelp add to the smoothness and spreadability of products such as cheese spreads and mayonnaise.

Science Online

Topic: Red Tides

Visit bookb.msscience.com for Web links to information about red tides and dinoflagellate blooms.

Activity Determine where red tides occur more frequently. Construct a map of the world and indicate where red tides have occurred in the last five years.

Importance of Algae

Have you thought about how important grasses are as a food source for animals that live on land? Cattle, deer, zebras, and many other animals depend on grasses as their main source of food. Algae sometimes are called the grasses of the oceans. Most animals that live in the oceans eat either algae for food or other animals that eat algae. You might think many-celled, large algae like kelp are the most important food source, but the one-celled diatoms and dinoflagellates are a more important food source for many organisms. Algae, such as *Euglena,* also are an important source of food for organisms that live in freshwater.

Walter H. Hodge/Peter Arnold, Inc.

Algae and the Environment Algae are important in the environment because they produce oxygen as a result of photosynthesis. The oxygen produced by green algae is important for most organisms on Earth, including you.

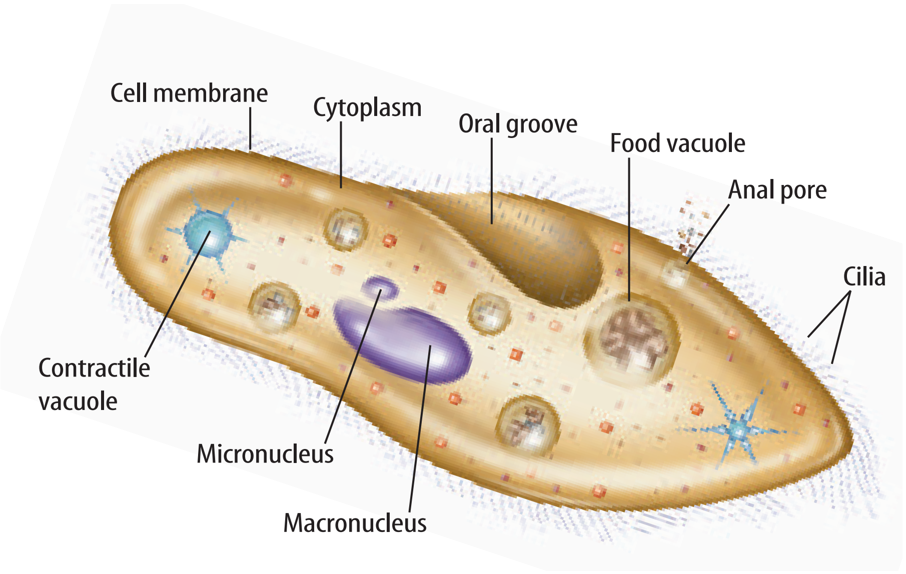
Under certain conditions, algae can reproduce rapidly and develop into what is known as an algal bloom. Because of the large number of organisms in a bloom, the color of the water appears to change. Red tides that appear along the east and Gulf coasts of the United States are the result of dinoflagellate blooms. Toxins produced by the dinoflagellates can cause other organisms to die and can cause health problems in humans.

Algae and You People in many parts of the world eat some species of red and brown algae. You probably have eaten foods or used products made with algae. Carrageenan (kar uh JEE nuhn), a substance found in the cell walls of red algae, has gelatinlike properties that make it useful to the cosmetic and food industries. It is usually processed from the red alga Irish moss, shown in **Figure 7.** Carrageenan gives toothpastes, puddings, and salad dressings their smooth, creamy textures. Another substance, algin (AL juhn), found in the cell walls of brown algae, also has gelatinlike properties. It is used to thicken foods such as ice cream and marshmallows. Algin also is used in making rubber tires and hand lotion.

Figure 7 Carrageenan, a substance extracted from Irish moss, is used for thickening dairy products such as chocolate milk.

Ancient deposits of diatoms are mined and used in insulation, filters, and road paint. The cell walls of diatoms produce the sparkle that makes some road lines visible at night and the crunch you might feel in toothpaste.

Reading Check *What are some uses by humans of algae?*



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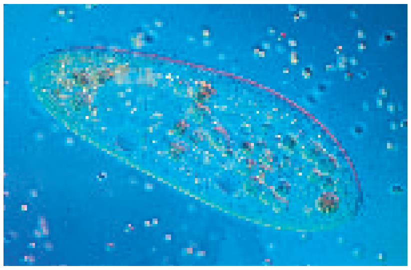


Figure 8 *Paramecium* is a typical ciliate found in many freshwater environments. These rapidly swimming protists consume bacteria.
Infer *Locate the vacuoles in the photo. What is their function?*

Animal-Like Protists

One-celled, animal-like protists are known as **protozoans.** Usually protozoans are classified by how they move. These complex organisms live in or on other living or dead organisms that are found in water or soil. Many protozoans have specialized vacuoles for digesting food and getting rid of excess water.

Ciliates As their name suggests, these protists have **cilia** (SIH lee uh)—short, threadlike structures that extend from the cell membrane. Ciliates can be covered with cilia or have cilia grouped in specific areas on the surface of the cell. The cilia beat in a coordinated way similar to rowboat oars. As a result, the organism moves swiftly in any direction. Organisms in this group include some of the most complex, one-celled protists and some of the largest, one-celled protists.

A typical ciliate is *Paramecium,* shown in **Figure 8.** *Paramecium* has two nuclei—a macronucleus and a micronucleus—another characteristic of the ciliates. The micronucleus is involved in reproduction. The macronucleus controls feeding, the exchange of oxygen and carbon dioxide, the amount of water and salts entering and leaving *Paramecium,* and other functions of *Paramecium.*

Ciliates usually feed on bacteria that are swept into the oral groove by the cilia. Once the food is inside the cell, a vacuole forms around it and the food is digested. Wastes are removed through the anal pore. Freshwater ciliates, like *Paramecium,* also have a structure called the contractile vacuole that helps get rid of excess water. When the contractile vacuole contracts, excess water is ejected from the cell.

Eric V. Grave/Photo Researchers

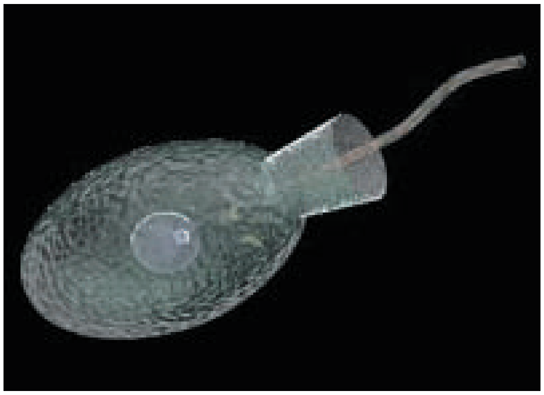


Figure 9 *Proterospongia* is a rare, freshwater protist. Some scientists hypothesize that this flagellate might share an ancestor with ancient animals.

Flagellates Protozoans called flagellates move through their watery environment by whipping their long flagella. Many species of flagellates live in freshwater, though some are parasites that harm their hosts.

Proterospongia, shown in **Figure 9,** is a member of one group of flagellates that might share an ancestor with ancient animals. These flagellates often grow in colonies of many cells that are similar in structure to cells found in animals called sponges. Like sponge cells, when *Proterospongia* cells are in colonies, they perform different functions. Moving the colony through the water or dividing, which increases the colony's size, are two examples of jobs that the cells of *Proterospongia* carry out.

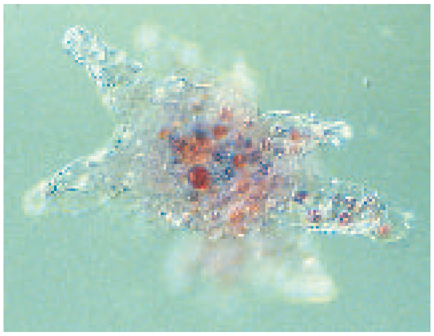
Movement with Pseudopods Some protozoans move through their environments and feed using temporary extensions of their cytoplasm called **pseudopods** (SEW duh pahdz). The word *pseudopod* means "false foot." These organisms seem to flow along as they extend their pseudopods. They are found in freshwater and saltwater environments, and certain types are parasites in animals.

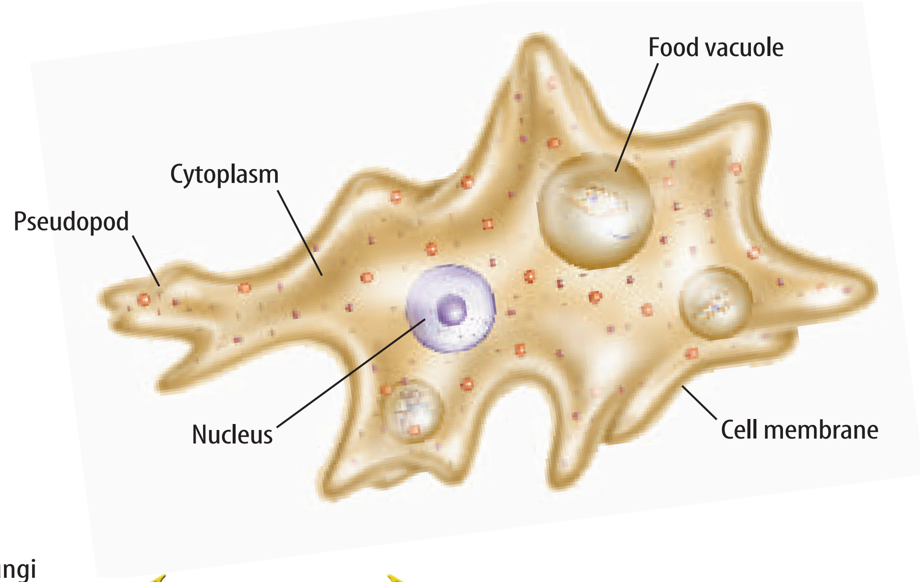
The amoeba shown in **Figure 10** is a typical member of this group. To obtain food, an amoeba extends the cytoplasm of a pseudopod on either side of a food particle such as a bacterium. Then the two parts of the pseudopod flow together and the particle is trapped. A vacuole forms around the trapped food. Digestion takes place inside the vacuole.

Although some protozoans of this group, like the amoeba, have no outer covering, others secrete hard shells around themselves. The white cliffs of Dover, England are composed mostly of the remains of some of these shelled protozoans. Some shelled protozoa have holes in their shells through which the pseudopods extend.

Figure 10 In many areas of the world, a disease-causing species of amoeba lives in the water. If it enters a human body, it can cause dysentery—a condition that can lead to a severe form of diarrhea.
Infer *why an amoeba is classified as a protozoan.*

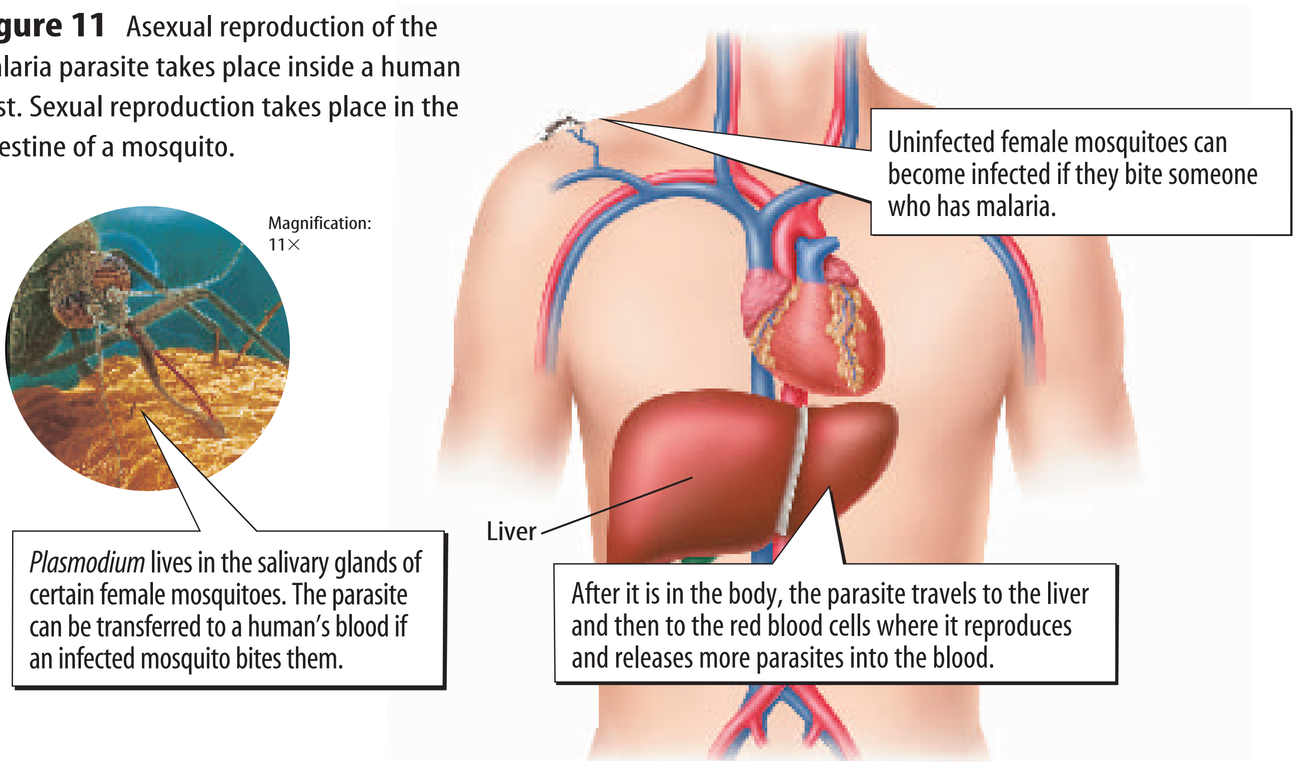
LM Magnification: 85×





(t)Kerry B. Clark, (b)Astrid & Hanns-Frieder Michler/Science Photo Library/Photo Researchers

Figure 11 Asexual reproduction of the malaria parasite takes place inside a human host. Sexual reproduction takes place in the intestine of a mosquito.



Other Protozoans One group of protozoans has no way of moving on their own. All of the organisms in this group are parasites of humans and other animals. These protozoans have complex life cycles that involve sexual and asexual reproduction. They often live part of their lives in one animal and part in another. The parasite that causes malaria is an example of a protozoan in this group. **Figure 11** shows the life cycle of the malaria parasite.

Importance of Protozoans

Like the algae, some protozoans are an important source of food for larger organisms. When some of the shelled protozoans die, they sink to the bottom of bodies of water and become part of the sediment. Sediment is a buildup of plant and animal remains and rock and mineral particles. The presence of these protists in sediments is used sometimes by field geologists as an indicator species. This tells them where petroleum reserves might be found beneath the surface of Earth.

Reading Check *Why are shelled protozoans important?*

One type of flagellated protozoan lives with bacteria in the digestive tract of termites. Termites feed mainly on wood. These protozoans and bacteria produce wood-digesting enzymes that help break down the wood. Without these organisms, the termites would be less able to use the chemical energy stored in wood.

INTEGRATE Health

African Sleeping Sickness The flagellate *Trypanosoma* is carried by the tsetse fly in Africa and causes African sleeping sickness in humans and other animals. It is transmitted to other organisms during bites from the fly. The disease affects the central nervous system. Research this disease and create a poster showing what you learn.

Lennart Nilsson/Albert Bonniers Forlag AB

Mini LAB

Observing Slime Molds

Procedure

1. Obtain live specimens of the slime mold ***Physarum polycephaalum*** from your teacher.
2. Observe the mold once each day for four days.
3. Using a **magnifying lens,** make daily drawings and observations of the mold as it grows.

Analysis

Predict the growing conditions under which the slime mold will change from the amoeboid form to the spore-producing form.

Disease in Humans The protozoans that may be most important to you are the ones that cause diseases in humans. In tropical areas, flies or other biting insects transmit many of the parasitic flagellates to humans. A flagellated parasite called *Giardia* can be found in water that is contaminated with wastes from humans or wild or domesticated animals. If you drink water directly from a stream, you could get this diarrhea-causing parasite.

Some amoebas also are parasites that cause disease. One parasitic amoeba, found in ponds and streams, can lead to a brain infection and death.

Funguslike Protists

Funguslike protists include several small groups of organisms such as slime molds, water molds, and downy mildews. Although all funguslike protists produce spores like fungi, most of them can move from place to place using pseudopods like the amoeba. All of them must take in food from an outside source.

Slime Molds As shown in **Figure 12,** slime molds are more attractive than their name suggests. Slime molds form delicate, weblike structures on the surface of their food supply. Often these structures are brightly colored. Slime molds have some protozoan characteristics. During part of their life cycle, slime molds move by means of pseudopods and behave like amoebas.

Most slime molds are found on decaying logs or dead leaves in moist, cool, shady environments. One common slime mold sometimes creeps across lawns and mulch as it feeds on bacteria and decayed plants and animals. When conditions become less favorable for slime molds, reproductive structures form on stalks and spores are produced.

Figure 12 Slime molds come in many different forms and colors ranging from brilliant yellow or orange to rich blue, violet, pink, and jet black.
Compare and contrast *how slime molds are similar to protists and fungi.*

Magnification: 5.25×

Magnification: 3×

(l)Ray Simons/Photo Researchers, (c)Matt Meadows/Peter Arnold, Inc., (r)Gregory G. Dimijian/P Re

Water Molds and Downy Mildews

Most members of this large, diverse group of funguslike protists live in water or moist places. Like fungi, they grow as a mass of threads over a plant or animal. Digestion takes place outside of these protists, then they absorb the organism's nutrients. Unlike fungi, the spores these protists produce have flagella. Their cell walls more closely resemble those of plants than those of fungi.

Some water molds are parasites of plants, and others feed on dead organisms. Most water molds appear as fuzzy, white growths on decaying matter, as shown in **Figure 13.** If you have an aquarium, you might see water molds attack a fish and cause its death. Another important type of protist is a group of plant parasites called downy mildew. Warm days and cool, moist nights are ideal growing conditions for them. They can live on aboveground parts of many plants. Downy mildews weaken plants and even can kill them.

Figure 13 Water mold, the threadlike material seen in the photo, grows on a dead salamander. In this case, the water mold is acting as a decomposer. This important process will return nutrients to the water.

Reading Check *How do water molds affect organisms?*

Applying Science

Is it a fungus or a protist?

Slime molds, such as the pipe cleaner slime shown in the photograph to the right, can be found covering moist wood. They can be white or bright red, yellow, or purple. If you look at a piece of slime mold on a microscope slide, you will see that the cell nuclei move back and forth as the cytoplasm streams along. This streaming of the cytoplasm is how a slime mold creeps over the wood.

Identifying the Problem

Should slime molds be classified as protists or as fungi?

Solving the Problem

1. What characteristics do slime molds share with protists? How are slime molds similar to protozoans and algae?
2. What characteristics do slime molds share with fungi? What characteristics do slime molds have that are different from fungi?
3. What characteristics did you compare to decide what group slime molds should be classified in? What other characteristics could scientists examine to help classify slime molds?

(t)Dwight Kuhn, (b)Mark Steinmetz

Figure 14 Downy mildews can have a great impact on agriculture and economies when they infect potatoes, sugar beets, grapes, and melons like those above.

Importance of the Funguslike Protists

Some of the organisms in this group are important because they help break down dead organisms. However, most funguslike protists are important because of the diseases they cause in plants and animals. One species of water mold that causes lesions in fish can be a problem when the number of this species in a given area is high. Fish farms and salmon spawning in streams can be greatly affected by a water mold spreading throughout the population. Water molds cause disease in other aquatic organisms including worms and even diatoms.

Economic Effects Downy mildews can have a huge effect on economies as well as social history. One of the most well-known members of this group caused the Irish potato famine during the 1840s. Potatoes were Ireland's main crop and the primary food source for its people. When the potato crop became infected with downy mildew, potatoes rotted in the fields, leaving many people with no food. A downy mildew infection of grapes in France during the 1870s nearly wiped out the entire French wine industry. Downy mildews, as shown in **Figure 14,** continue to infect crops such as lettuce, corn, and cabbage, as well as tropical avocados and pineapples.

section 1 review

Summary

What is a protist?

- Protists can reproduce asexually or sexually.

Plantlike Protists

- Algae can make their own food.
- Euglenoids are both animal-like and plantlike.
- Seaweeds are many-celled algae.
- Green algae are an important source of oxygen and food for many organisms on Earth.
- Algae can be used to thicken food or cosmetics.

Animal-like Protists

- Protozoans are one-celled consumers. Some protozoans are parasites.
- Some protozoans form symbiotic relationships; other protozoans can cause disease.

Funguslike Protists

- Funguslike protists take in energy from other organisms.

Self Check

1. **Identify** the characteristics common to all protists.
2. **Compare and contrast** the characteristics of animal-like, plantlike, and funguslike protists.
3. **Explain** how plantlike protists are classified into different groups.
4. **Classify** What protozoan characteristics do scientists use to organize protozoans into groups?
5. **Think Critically** Why are there few fossils of certain groups of protists?

Applying Skills

6. **Make and Use a Table** Make a table of the positive and negative effects that protists might have on your life and health.
7. **Use a spreadsheet** to make a table that compares the characteristics of the three groups of protozoans. Include *example organisms, method of transportation,* and *other characteristics.*

Richard Calentine/Visuals Unlimited
Science Online bookb.msscience.com/self_check_quiz
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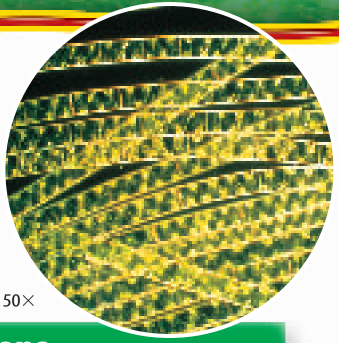
LAB

Comparing Algae and Protozoans



Magnification: 50×

Algae and protozoans have characteristics that are similar enough to place them in the same group—the protists. However, the variety of protist forms is great. In this lab, you can observe many of the differences among protists.

Real-World Question

What are the differences between algae and protozoans?

Goals

- **Draw and label** the organisms you examine.
- **Observe** the differences between algae and protozoans.

Materials

cultures of *Paramecium, Amoeba, Euglena,* and *Spirogyra*
**prepared slides of the organisms listed above*
prepared slide of slime mold
microscope slides (4)
coverslips (4)
microscope
**stereomicroscope*
dropper
**Alternate materials*

Safefy Precautions

Procedure

1. Copy the data table in your Science Journal.
2. Make a wet mount of the *Paramecium* culture. If you need help, refer to Student Resources at the back of the book.

Protist Observations

Protist	Drawing	Observations
Paramecium	Do not write in this book.	
Amoeba		
Euglena		
Spirogyra		
Slime mold		

3. **Observe** the wet mount first under low and then under high power. Record your observations in the data table. Draw and label the organism that you observed.
4. Repeat steps 2 and 3 with the other cultures. Return all preparations to your teacher and wash your hands.
5. **Observe** the slide of slime mold under low and high power. Record your observations.

Conclude and Apply

1. **Describe** the structure used for movement by each organism that moves.
2. **List** the protists that make their own food and explain how you know that they can.
3. **Identify** the protists you observed with animal-like characteristics.

Communicating Your Data

Share the results of this lab with your classmates. **For more help, refer to the Science Skill Handbook.**

Biophoto Associates/Science Source/Photo Researchers

section 2

Fungi

as you read

What You'll Learn

- **Identify** the characteristics shared by all fungi.
- **Classify** fungi into groups based on their methods of reproduction.
- **Differentiate** between the imperfect fungi and all other fungi.

Why It's Important

Fungi are important sources of food and medicines, and they help recycle Earth's wastes.

Review Vocabulary

photosynthesis: a process in which chlorophyll containing organisms use energy from light and change carbon dioxide and water into simple sugars and oxygen gas

New Vocabulary

- hyphae
- saprophyte
- spore
- basidium
- ascus
- budding
- sporangium
- lichen
- mycorrhizae

What are fungi?

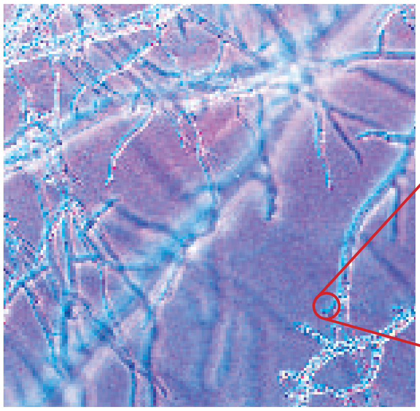
Do you think you can find any fungi in your house or apartment? You have fungi in your home if you have mushroom soup or fresh mushrooms. What about that package of yeast in the cupboard? Yeasts are a type of fungus used to make some breads and cheeses. You also might find fungus growing on a loaf of bread or an orange, or mildew fungus growing on your shower curtain.

Origin of Fungi Although fossils of fungi exist, most are not useful in determining how fungi are related to other organisms. Some scientists hypothesize that fungi share an ancestor with ancient, flagellated protists and slime molds. Other scientists hypothesize that their ancestor was a green or red alga.

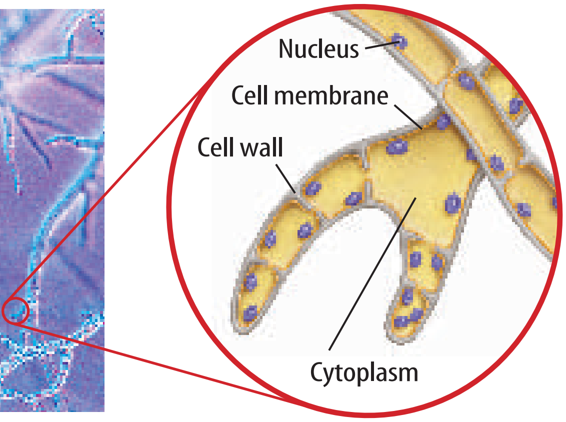
Structure of Fungi Most species of fungi are many-celled. The body of a fungus is usually a mass of many-celled, threadlike tubes called **hyphae** (HI fee), as shown in **Figure 15.** The hyphae produce enzymes that help break down food outside of the fungus. Then, the fungal cells absorb the digested food. Because of this, most fungi are known as saprophytes. **Saprophytes** are organisms that obtain food by absorbing dead or decaying tissues of other organisms. Other fungi are parasites. They obtain their food directly from living things.

Figure 15 The hyphae of fungi are involved in the digestion of food, as well as reproduction.

Stained LM Magnification: 175×



Threadlike, microscopic hyphae make up the body of a fungus.



The internal structure of hyphae.

James W. Richardson/Visuals Unlimited

Other Characteristics of Fungi

What other characteristics do all fungi share? Because some fungi grow anchored in soil and have a cell wall around each cell, fungi once were classified as plants. But fungi don't have the specialized tissues and organs of plants, such as leaves and roots. Unlike most plants, fungi do not contain chlorophyll and cannot undergo photosynthesis.

Fungi grow best in warm, humid areas, such as tropical forests or between toes. You need a microscope to see some fungi, but in Michigan one fungus was found growing underground over an area of about 15 hectares. In the state of Washington, another type of fungus found in 1992 was growing throughout nearly 600 hectares of soil.

Reproduction

Asexual and sexual reproduction in fungi usually involves the production of spores. A **spore** is a waterproof reproductive cell that can grow into a new organism. In asexual reproduction, cell division produces spores. These spores will grow into new fungi that are genetically identical to the fungus from which the spores came.

Fungi are not identified as either male or female. Sexual reproduction can occur when the hyphae of two genetically different fungi of the same species grow close together. If the hyphae join, a reproductive structure will grow, as shown in **Figure 16.** Following meiosis in these structures, spores are produced that will grow into fungi. These fungi are genetically different from either of the two fungi whose hyphae joined during sexual reproduction. Fungi are classified into three main groups based on the type of structure formed by the joining of hyphae.

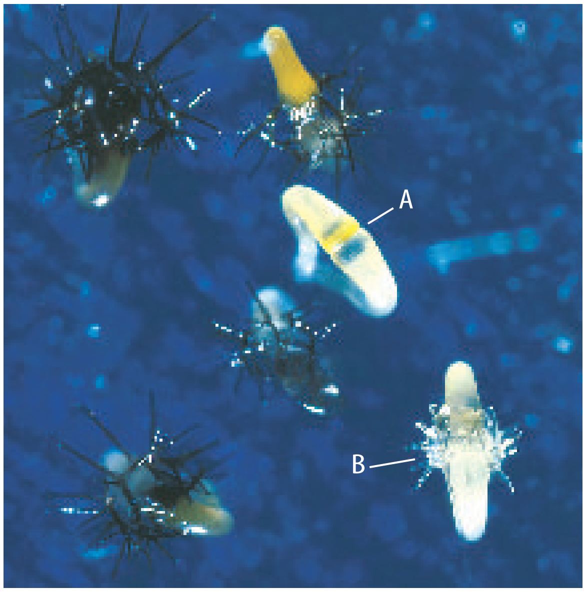
Reading Check *How are fungi classified?*

Science Online

Topic: Unusual Fungi

Visit bookb.msscience.com for Web links to information about *Armillaria ostoyae* and other unusual fungi.

Activity Prepare an informational brochure about unusual fungi. Include illustrations and descriptions of at least three different kinds. Where do you find these fungi?



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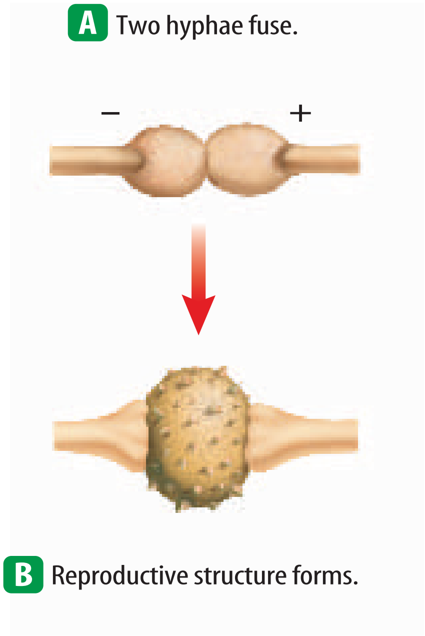

Figure 16 When two genetically different fungi of the same species meet, a reproductive structure, in this case a zygospore **B**, will be formed. The new fungi will be genetically different from either of the two original fungi.

Carolina Biological Supply/Phototake, NYC

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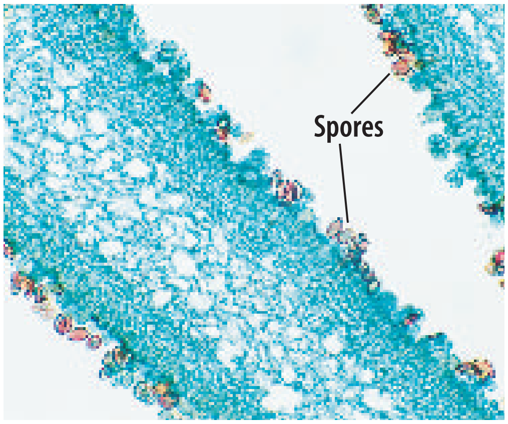
Figure 17 Club fungi, like this mushroom, form a reproductive structure called a basidium. Each basidium produces four balloonlike structures called basidiospores. Spores will be released from these as the final step in sexual reproduction.



Stained LM Magnification: 18×

Club Fungi

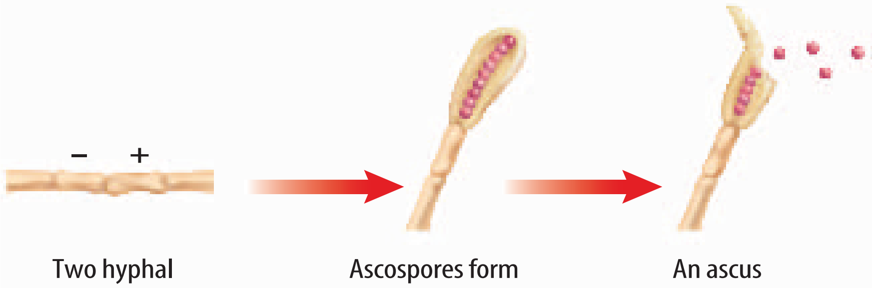
The mushrooms shown in **Figure 17** are probably the type of fungus that you are most familiar with. The mushroom is only the reproductive structure of the fungus. Most of the fungus grows as hyphae in the soil or on the surface of its food source. These fungi commonly are known as club fungi. Their spores are produced in a club-shaped structure called a **basidium** (buh SIH dee uhm) (plural, *basidia*).

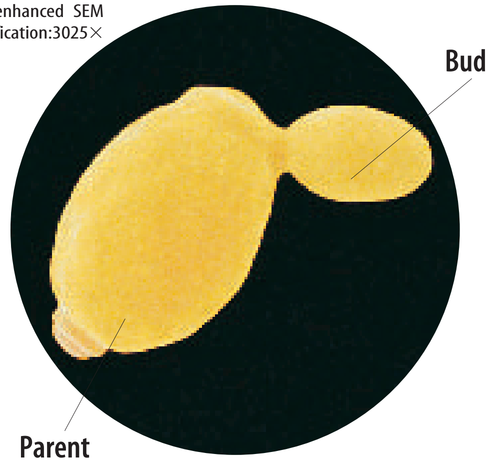
Sac Fungi

Yeasts, molds, morels, and truffles are all examples of sac fungi—a diverse group containing more than 30,000 different species. The spores of these fungi are produced in a little, saclike structure called an **ascus** (AS kus), as shown in **Figure 18.**

Although most fungi are many-celled, yeasts are one-celled organisms. Yeasts reproduce sexually by forming spores and reproduce asexually by budding, as illustrated in the right photo below. **Budding** is a form of asexual reproduction in which a new organism forms on the side of a parent organism. The two organisms are genetically identical.

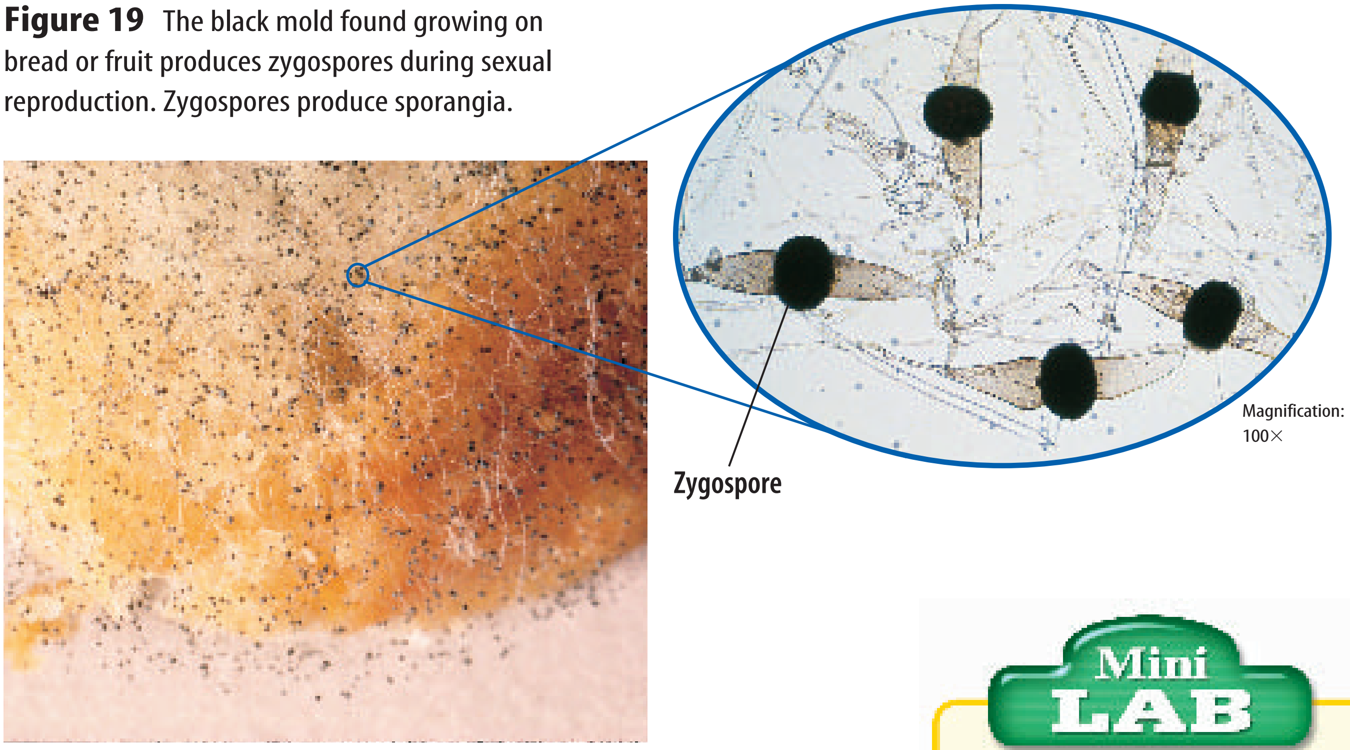
Figure 18 The spores of a sac fungus are released when the tip of an ascus breaks open.





(tl)Mark Steinmetz, (tr)Ken Wagner/Visuals Unlimited, (b)Dennis Kunkel

Figure 19 The black mold found growing on bread or fruit produces zygospores during sexual reproduction. Zygospores produce sporangia.



Zygote Fungi and Other Fungi

The fuzzy black mold that you sometimes find growing on a piece of fruit or an old loaf of bread, as shown in **Figure 19,** is a type of zygospore fungus. Fungi that belong to this group produce spores in a round spore case called a **sporangium** (spuh RAN jee uhm) (plural, *sporangia*) on the tips of upright hyphae. When each sporangium splits open, hundreds of spores are released into the air. Each spore will grow and reproduce if it lands in a warm, moist area that has a food supply.

Reading Check *What is a sporangium?*

Some fungi either never reproduce sexually or never have been observed reproducing sexually. Because of this, these fungi are difficult to classify. They usually are called imperfect fungi because there is no evidence that their life cycle has a sexual stage. Imperfect fungi reproduce asexually by producing spores. When the sexual stage of one of these fungi is observed, the species is classified immediately in one of the other three groups.

Penicillium is a fungus that is difficult to classify. Some scientists classify *Penicillium* as an imperfect fungi. Others think it should be classified as a sac fungus based on the type of spores it forms during asexual reproduction. Another fungus, which causes pneumonia, has been classified recently as an imperfect fungus. Like *Penicillium*, scientists do not agree about which group to place it in.

Mini LAB

Interpreting Spore Prints

Procedure

1. Obtain several **mushrooms from the grocery store** and let them age until the undersides look dark brown.
2. Remove the stems. Place the mushroom caps with the gills down on a piece of **unlined white paper.**
3. Let the mushroom caps sit undisturbed overnight and remove them from the paper the next day.

Analysis

1. **Draw** and label the results in your **Science Journal.** Describe the marks on the page and what might have made them.
2. **Estimate** the number of mushrooms that could be produced from a single mushroom cap.

Try at Home

(l)Science VU/Visuals Unlimited, (r)J.W. Richardson/Visuals Unlimited

Figure 20 Lichens can look like a crust on bare rock, appear leafy, or grow upright. All three forms can grow near each other.
Determine *one way lichens might be classified.*

Lichens

The colorful organisms in **Figure 20** are lichens. A **lichen** (LI kun) is an organism that is made of a fungus and either a green alga or a cyanobacterium. These two organisms have a relationship in which they both benefit. The alga or cyanobacterium lives among the threadlike strands of the fungus. The fungus gets food made by the green alga or cyanobacterium. The green alga or cyanobacterium gets a moist, protected place to live.

Importance of Lichens For many animals, including caribou and musk oxen, lichens are an important food source.

Lichens also are important in the weathering process of rocks. They grow on bare rock and release acids as part of their metabolism. The acids help break down the rock. As bits of rock accumulate and lichens die and decay, soil is formed. This soil supports the growth of other species.

Scientists also use lichens as indicator organisms to monitor pollution levels, as shown in **Figure 21.** Many species of lichens are sensitive to pollution. When these organisms show a decline in their health or die quickly, it alerts scientists to possible problems for larger organisms.

Fungi and Plants

Some fungi interact with plant roots. They form a network of hyphae and roots known as **mycorrhizae** (mi kuh RI zee). About 80 percent of plants develop mycorrhizae. The fungus helps the plant absorb more of certain nutrients from the soil better than the roots can on their own, while the plant supplies food and other nutrients to the fungi. Some plants, like the lady's slipper orchids shown in **Figure 22,** cannot grow without the development of mycorrhizae.

Reading Check *Why are mycorrhizae so important to plants?*

Figure 22 Many plants, such as these orchids, could not survive without mycorrhizae to help absorb water and important minerals from soil.

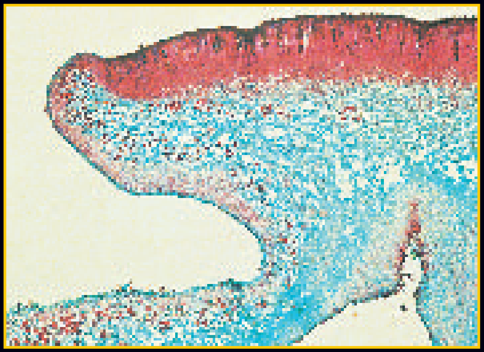
(tl)Bill Bachman/Photo Researchers, (tc)Frank Orel/Stone/Getty Images, (tr)Charles Kingery/Ph...e, ...Sce

NATIONAL GEOGRAPHIC

VISUALIZING LICHENS AS AIR QUALITY INDICATORS

Figure 21

Widespread, slow growing, and with long life spans, lichens come in many varieties. Lichens absorb water and nutrients mainly from the air rather than the soil. Because certain types are extremely sensitive to toxic environments, lichens make natural, inexpensive, air-pollution detectors.



A lichen consists of a fungus and an alga or cyanobacterium living together in a partnership that benefits both organisms. In this cross section of a lichen (50x), reddish-stained bits of fungal tissue surround blue-stained algal cells.

Can you see a difference between these two red alder tree trunks? White lichens cover one trunk but not the other. Red alders are usually covered with lichens such as those seen in the photo on the left. Lichens could not survive on the tree on the right because of air pollution.

Evernia lichens, left, sicken and die when exposed to sulfur dioxide, a common pollutant emitted by coal-burning industrial plants such as the one above.

CONTENTS

hot ... ociates/Photo Researchers, (bl)L. West/Photo Researchers, (br)Larry Lee Photography/CORBIS

INTEGRATE Career

Biotechnology Living cells and materials produced by cells are used in biotechnology to develop products that benefit society. Careers in biotechnology include laboratory research and development, quality control, biostatistician, and product development. Through biotechnology, some fungi have been developed that can be used as natural pesticides to control pests like termites, tent caterpillars, aphids, and citrus mites.

INTEGRATE Earth Science

Fossilized Fungus In 1999, scientists discovered a fossilized fungus in a 460 million-year-old rock. The fossil was a type of fungus that forms associations with plant roots. Scientists have known for many years that the first plants could not have survived moving from water to land alone. Early plants did not have specialized roots to absorb nutrients. Also, tubelike cells used for transporting water and nutrients to leaves were too simple.

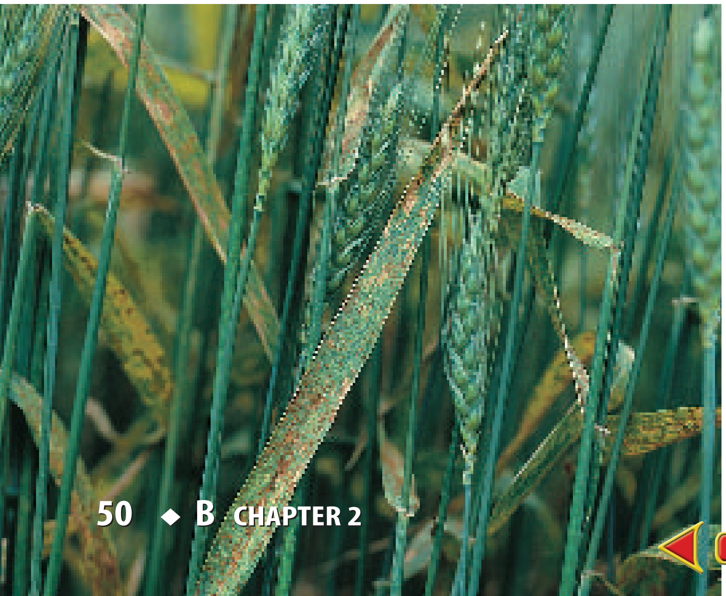
Scientists have hypothesized that early fungi attached themselves to the roots of early plants, passing along nutrients taken from the soil. Scientists suggest that it was this relationship that allowed plants to move successfully from water onto land about 500 million years ago. Until the discovery of this fossil, no evidence had been found that this type of fungus existed at that time.

Importance of Fungi

As mentioned in the beginning of this chapter, some fungi are eaten for food. Cultivated mushrooms are an important food crop. However, wild mushrooms never should be eaten because many are poisonous. Some cheeses are produced using fungi. Yeasts are used in the baking industry. Yeasts use sugar for energy and produce alcohol and carbon dioxide as waste products. The carbon dioxide causes doughs to rise.

Agriculture Many fungi are important because they cause diseases in plants and animals. Many sac fungi are well-known by farmers because they damage or destroy plant crops. Diseases caused by sac fungi include Dutch elm disease, apple scab, and ergot disease of rye. Smuts and rust, shown in **Figure 23,** are club fungi. They cause billions of dollars worth of damage to food crops each year.

Figure 23 Rusts can infect the grains used to make many cereals including wheat (shown below), barley, rye, and oats. Not all fungi are bad for agriculture. Some are natural pesticides. This dead grasshopper (right) is infected with a fungal parasite.



(l)Nigel Cattlin/Holt Studios International/Photo Researchers, (r)Michael Fogden/Earth Scenes

Health and Medicine Fungi can cause diseases in humans and animals. Ringworm and athlete's foot are skin infections caused by species of imperfect fungi. Other fungi can cause respiratory infections.

The effects of fungi on health and medicine are not all negative. Some species of fungi naturally produce antibiotics that keep bacteria from growing on or near them. The antibiotic penicillin is produced by the imperfect fungi *Penicillium.* This fungus is grown commercially, and the antibiotic is collected to use in fighting bacterial infections. Cyclosporine, an important drug used to help fight the body's rejection of transplanted organs, also is derived from a fungus. There are many more examples of breakthroughs in medicine as a result of studying and discovering new uses of fungi. In fact, there is a worldwide effort among scientists who study fungi to investigate soil samples to find more useful drugs.

Figure 24 Fungi have an important role as decomposers in nature.
Explain *why fungi are called nature's recyclers.*

Decomposers As important as fungi are in the production of different foods and medicines, they are most important as decomposers that break down organic materials. Food scraps, clothing, and dead plants and animals are made of organic material. Often found on rotting logs, as shown in **Figure 24,** fungi break down these materials. The chemicals in these materials are returned to the soil where plants can reuse them. Fungi, along with bacteria, are nature's recyclers. They keep Earth from becoming buried under mountains of organic waste materials.

section 2 review

Summary

What are fungi?

- Fungi are consumers and reproduce both sexually and asexually.
- There are three main classifications of fungi.

Lichens

- Lichens consist of a fungus and either a green alga or a cyanobacterium.
- They help break down rocks and form soil.

Fungi and Plants

- Mycorrhizae are a network of plant roots and fungi hyphae that interact to obtain nutrients.

Importance of Fungi

- Fungi are most important as decomposers.

Self Check

1. **List** characteristics common to all fungi.
2. **Explain** how fungi are classified into different groups.
3. **Compare and contrast** imperfect fungi and other groups of fungi.
4. **List** ways lichens are important.
5. **Think Critically** If an imperfect fungus was found to produce basidia under certain environmental conditions, how would the fungus be reclassified?

Applying Math

6. **Use Proportions** Of the 100,000 fungus species, approximately 30,000 are sac fungi. What percentage of fungus species are sac fungi?

Science Online bookb.msscience.com/self_check_quiz

Ray Elliott

LAB

Model and Invent

Creating a Fungus Field Guide

Goals

- **Identify** the common club fungi found in the woods or grassy areas near your home or school.
- **Create** a field guide to help future science students identify these fungi.

Possible Materials

collection jars
magnifying lens
microscopes
microscope slides and coverslips
field guide to fungi or club fungi
art supplies

Safety Precautions

WARNING: *Do not eat any of the fungi you collect. Do not touch your face during the lab.*

Real-World Question

Whether they are hiking deep into a rain forest in search of rare tropical birds, diving to coral reefs to study marine worms, or peering into microscopes to identify strains of bacteria, scientists all over the world depend on reliable field guides. Field guides are books that identify and describe certain types of organisms or the organisms living in a specific environment. Scientists find field guides for a specific area especially helpful. How can you create a field guide for the club fungi living in your area? What information would you include in a field guide of club fungi?

Make A Model

1. Decide on the locations where you will conduct your search.
2. Select the materials you will need to collect and survey club fungi.
3. Design a data table in your Science Journal to record the fungi you find.
4. Decide on the layout of your field guide. What information about the fungi you will include? What drawings you will use? How will you group the fungi?

Mark Steinmetz

5. **Describe** your plan to your teacher and ask your teacher how it could be improved.
6. **Present** your ideas for collecting and surveying fungi, and your layout ideas for your field guide to the class. Ask your classmates to suggest improvements in your plan.

Test Your Model

1. Search for samples of club fungi. **Record** the organisms you find in your data table. Use a fungus field guide to identify the fungi you discover. Do not pick or touch any fungi that you find unless you have permission.
2. Using your list of organisms, complete your field guide of club fungi as planned.
3. When finished, give your field guide to a classmate to identify a club fungus.

Analyze Your Data

1. **Compare** the number of fungi you found to the total number of organisms listed in the field guide you used to identify the organisms.
2. **Analyze** the problems you may have had while collecting and identifying your fungi. Suggest steps you could take to improve your collection and identification methods.
3. **Analyze** the problems you had while creating your field guide. Suggest ways your field guide could be improved.

Conclude and Apply

Infer why your field guide would be more helpful to future science students in your school than the fungus field guide you used to identify organisms.

Communicating Your Data

Compare your field guide with those assembled by your classmates. Combine all the information on local club fungi compiled by your class to create a classroom field guide to club fungi.

Stained LM Magnification: 80×

(t)Mark Steinmetz, (b)Ken Wagner/Visuals Unlimited

Chocolate SOS

Can a fungus protect cacao trees under attack?

Pods contain dozens of beans.

Losing Beans

Chocolate is made from seeds (cocoa beans) that grow in the pods on the tropical cacao tree. The monoculture (growing one type of crop) of modern fields has produced huge crops of cocoa beans, but also has enabled destructive fungi to sweep through cacao fields. A disease that attacks one plant of a species in a monoculture will rapidly spread to all plants in the monoculture. There are fewer healthy cacao trees today than there were several years ago. Since the blight began in the late 1980s, the world has lost three million tons of cocoa beans. Brazil, once the top producer and exporter of cocoa beans, harvested only 80,000 tons in 2000—the smallest harvest in 30 years.

A diseased pod from a cacao tree

Unless something stops the fungi that are destroying trees, there could be a lot less chocolate in the future. Your favorite chocolate bars could become more expensive and harder to find.

A Natural Cure

Farmers tried using traditional chemical sprays to fight the fungus, but they were ineffective because the tropical rains washed away the sprays. Now, agriculture scientists are working on a "natural solution" to the problem. They are using beneficial fungi (strains of *Trichoderma*) to fight the harmful fungi attacking the cocoa trees. When sprayed on trees, *Trichoderma* stops the spread of the harmful fungi. The test treatments in Brazil and Peru have reduced the destruction of the trees by between 30 and 50 percent.

Don't expect your favorite chocolate bars to disappear from stores anytime soon. Right now, world cocoa bean supplies still exceed demand. But if the spread of the epidemic can't be stopped, those chocolate bars could become slightly more expensive and a little harder to find.

Concept Map Use the library and other sources to learn the steps in making chocolate—from harvesting cacao beans to packing chocolate products for sale? Draw a concept map that shows the steps. Compare your concept map with those of your classmates.

Science Online
For more information, visit bookb.msscience.com/time

(t)Alvarode Leiva/Liaison, (b)Courtesy Beltsville Agricultural Research Center-West/US

chapter 2 Study Guide

Reviewing Main Ideas

Section 1 Protists

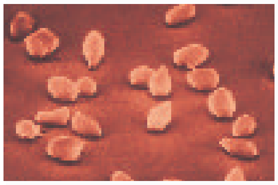
1. Protists are one-celled or many-celled eukaryotic organisms. They can reproduce asexually, resulting in two new cells that are genetically identical. Protists also can reproduce sexually and produce genetically different offspring.
2. The protist kingdom has members that are plantlike, animal-like, and funguslike.
3. Protists are thought to have evolved from a one-celled organism with a nucleus and other cellular structures.
4. Plantlike protists have cell walls and contain chlorophyll.
5. Animal-like protists can be separated into groups by how they move.
6. Funguslike protists have characteristics of protists and fungi.

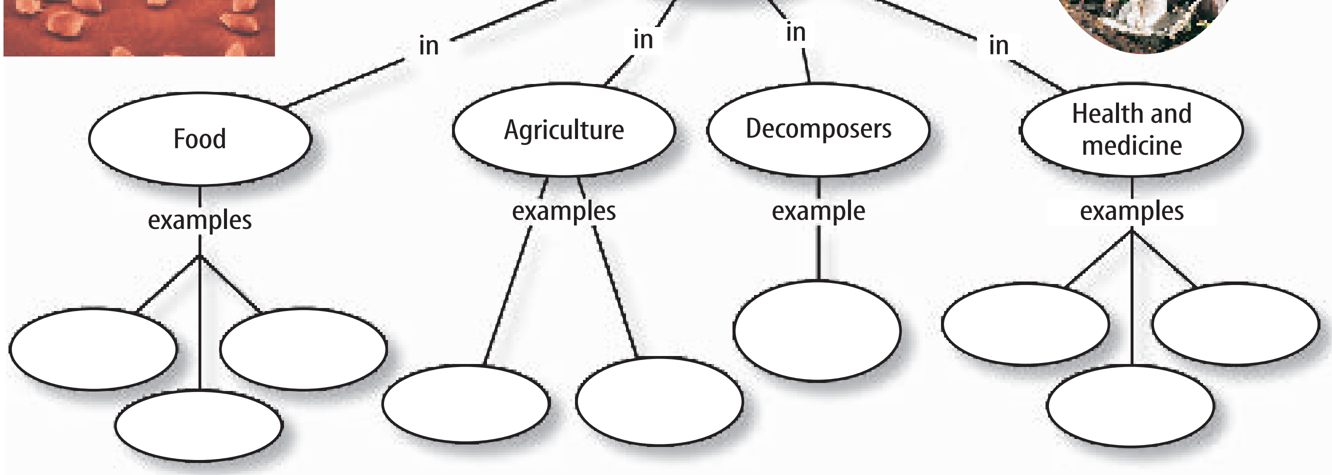
Section 2 Fungi

1. Most species of fungi are many-celled. The body of a fungus consists of a mass of threadlike tubes.
2. Fungi are saprophytes or parasites—they feed off other things because they cannot make their own food.
3. Fungi reproduce using spores.
4. The three main groups of fungi are club fungi, sac fungi, and zygote fungi. Fungi that cannot be placed in a specific group are called imperfect fungi. Fungi are placed into one of these groups according to the structures in which they produce spores.
5. A lichen is an organism that consists of a fungus and a green alga or cyanobacterium.

Visualizing Main Ideas

Copy and complete the following concept map on a separate sheet of paper.





(l)Michael Delaney/Visuals Unlimited, (r)Mark Steinmetz

chapter 2 Review

Using Vocabulary

algae p. 33	mycorrhizae p. 48
ascus p. 46	protist p. 32
basidium p. 46	protozoan p. 37
budding p. 46	pseudopod p. 38
cilia p. 37	saprophyte p. 44
flagellum p. 34	sporangium p. 47
hyphae p. 44	spore p. 45
lichen p. 48	

Write the vocabulary word that matches each of these descriptions.

1. reproductive cell of a fungus
2. organisms that are animal-like, plantlike, or funguslike
3. threadlike structures used for movement
4. plantlike protists
5. organism made up of a fungus and an alga or a cyanobacterium
6. reproductive structure made by sac fungi
7. threadlike tubes that make up the body of a fungus
8. structure used for movement formed by oozing cytoplasm

Checking Concepts

Choose the word or phrase that best answers the question.

9. Which type of protist captures food, does not have cell walls, and can move from place to place?
   A) algae **C)** fungi
   B) protozoans **D)** lichens

10. Which of the following organisms cause red tides when found in large numbers?
    A) *Euglena* **C)** *Ulva*
    B) diatoms **D)** dinoflagellates

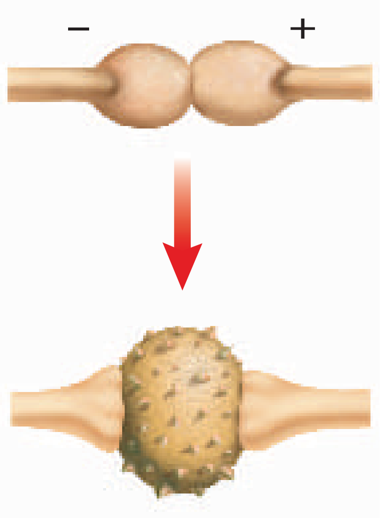
11. Algae are important for which of the following reasons?
    A) They are a food source for many aquatic organisms.
    B) Parts of algae are used in foods that humans eat.
    C) Algae produce oxygen as a result of the process of photosynthesis.
    D) all of the above

12. Where would you most likely find funguslike protists?
    A) on decaying logs
    B) in bright light
    C) on dry surfaces
    D) on metal surfaces

13. Where are spores produced in mushrooms?
    A) sporangia **C)** ascus
    B) basidia **D)** hyphae

14. Which of the following is used as an indicator organism?
    A) club fungus **C)** slime mold
    B) lichen **D)** imperfect fungus

Use the illustration below to answer question 15.



15. What is the reproductive structure, shown in the lower image above, called?
    A) hypha **C)** basidium
    B) zygospore **D)** ascus

Science Online bookb.msscience.com/vocabulary_puzzlemaker
CONTENTS

Thinking Critically

16. **Identify** what kind of environment is needed to prevent fungal growth.

17. **Infer** why algae contain pigments other than just chlorophyll.

18. **Compare and contrast** the features of fungi and funguslike protists.

19. **List** some advantages plants have when they form associations with fungi.

20. **Explain** the adaptations of fungi that enable them to get food.

21. **Recognize Cause and Effect** A leaf sitting on the floor of a rain forest will decompose in six weeks. A leaf on the floor of a temperate forest will take up to a year to decompose. Explain how this is possible.

22. **Compare and Contrast** Make a chart comparing and contrasting the different ways protists and fungi can obtain food.

23. **Make and Use Tables** Copy and complete the following table that compares the different groups of fungi.

Fungi Comparisons

Fungi Group	Structure Where Sexual Spores Are Produced	Examples
Club fungi		Do not write in this book.
	Ascus	
Zygospore fungi		
	No sexual spores produced	

24. **Identify and Manipulate Variables and Controls** You find a new and unusual fungus growing in your refrigerator. Design an experiment to determine to which fungus group it should be classified.

Performance Activities

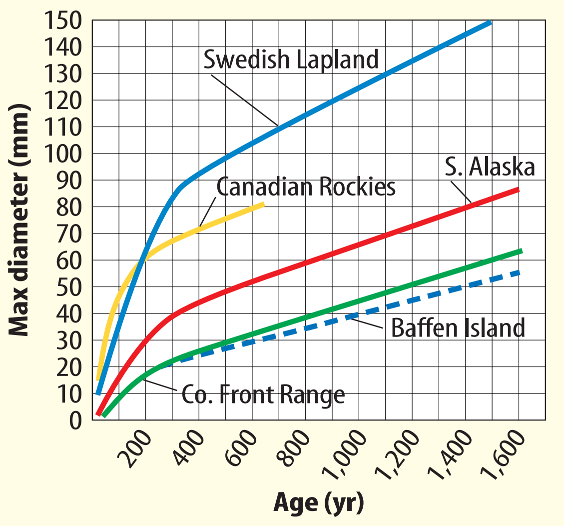
25. **Poster** Research the different types of fungi found in the area where you live. Determine to which group each fungus belongs. Create a poster to display your results and share them with your class.

Applying Math

26. **Lichen Growth** Sometimes the diameter of a lichen colony is used to estimate the age of the rock it is growing on. In some climates, it may take 100 years for a lichen colony to increase its diameter by 50 mm. Estimate how old a rock tombstone is if the largest lichen colony growing on it has a diameter of 150 mm.

Use the graph below to answer question 27.

Lichen Growth Rates

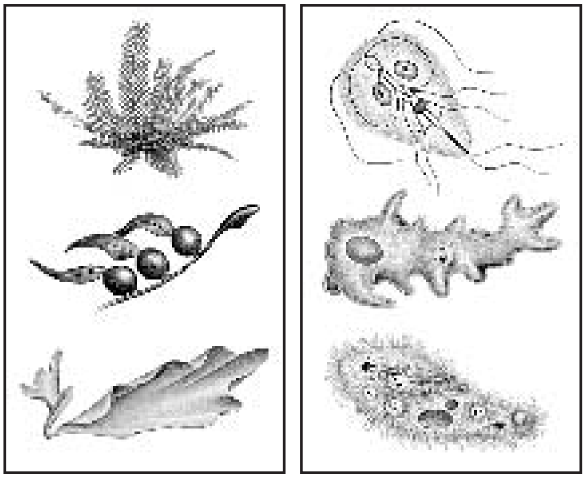


27. **Climate and Growth** The graph above illustrates lichen growth rates in different climates. According to the graph, which climate is the most favorable for lichen growth? What is the difference between the diameter of a 200-year-old colony in the Swedish Lapland compared to a 200-year-old colony on Baffen Island?

Part 1 Multiple Choice

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

Use the illustration below to answer questions 1–3.



1. Which of the following organisms would belong in Group B?
   A) kelp **C)** diatom
   B) grass **D)** *Paramecium*

2. Which of the following is a characteristic of Group B?
   A) makes own food
   B) has specialized ways to move
   C) absorbs food from the surroundings
   D) has cell walls

3. Which of the following is NOT a method of moving used by the protists in Group B?
   A) pseudopod **C)** flagella
   B) cilia **D)** vacuole

Test-Taking Tip

Go at Your Own Pace Stay focused during the test and don't rush, even if you notice that other students are finishing the test early.

4. Which of the following is a protozoan?
   A) ciliate **C)** kelp
   B) diatom **D)** bacteria

Use the table below to answer questions 5–7.

Diseases Caused by Protozoans		
Disease	**Source**	**Protozoan**
Giardiasis	Contaminated water	*Giardia*
Malaria	Mosquito bite	*Plasmodium*
Dysentery	Contaminated water	*Entamoeba*
Sleeping sickness	Tsetse fly bite	*Trypanosoma*
Toxoplasmosis	Contaminated soil; eating undercooked meat that contains the organism	*Toxoplasma*

5. According to the chart, which of the following disease-carrying protozoan can be transmitted to humans by a bite from another animal?
   A) *Giardia* **C)** *Entamoeba*
   B) *Plasmodium* **D)** *Toxoplasma*

6. Based on the information in the chart, which disease can be prevented by purifying water used for drinking and cooking, and by washing fruits and vegetables?
   A) malaria **C)** sleeping sickness
   B) dysentery **D)** toxoplasmosis

7. According to the chart, which protozoan disease can be prevented by cooking meat thoroughly?
   A) malaria **C)** sleeping sickness
   B) dysentery **D)** toxoplasmosis

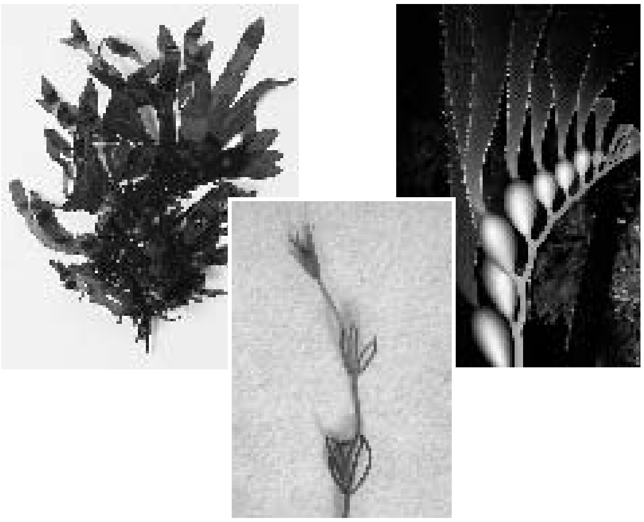
8. Where are the spores produced in the fuzzy black mold that grows on bread?
   A) basidia **C)** ascus
   B) sporangia **D)** hyphae

Part 2 Short Response/Grid In

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

9. Brown algae can grow at 35 m and red algae can grow at 200 m. Approximately how many times deeper than brown algae can red algae grow?

Use the illustration below to answer questions 10–11.



10. What type of protist is shown in the illustration above?

11. What pigment do all the organisms contain that absorbs light?

12. How are slime molds like protozoa?

13. How are saprophytes different from parasites?

14. Juan is making bread dough. “Don’t forget to add fungus,” Aunt Inez jokes. What did she mean?

15. One fungus found in Washington state was growing throughout 600 hectares of soil. Another fungus in Michigan was growing underground over an area of 15 hectares. How many times bigger was the fungus that was growing in Washington state?

Part 3 Open Ended

Record your answers on a sheet of paper.

16. Compare and contrast asexual and sexual reproduction.

17. Discuss the ways that algae are useful for humans.

18. Compare and contrast fungi and downy mildews.

Use the table below to answer questions 19–21.

Newly Identified Organisms		
Characteristic	**Organism A**	**Organism B**
Movement	No	Yes
One-celled or many-celled	Many-celled	One-celled
Cell walls	Yes	No
Method of reproduction	Sexual	Sexual
Makes own food	Only some cells	No
Contains chlorophyll	Only found in some cells	No
Method of obtaining food	Made by some of the organism’s cells; nutrients and water absorbed from surroundings	Sweeps food into oral groove
Where found	Bare rock	Freshwater

19. Dr. Seung discovered two new organisms. Their characteristics are listed in the table above. How would you classify organism B? How do you know?

20. What specialized way of moving would you expect to see if you examined organism B? Why?

21. How would you classify organism A? How do you know?

ark ... er Photography, Inc., (c)Robert Calentine/Visuals Unlimited, (r)Henry C. Wolcott III/Getty Images

chapter 3

Plants

chapter preview

sections

1 An Overview of Plants

2 Seedless Plants

3 Seed Plants

Lab *Identifying Conifers*

Lab *Plants as Medicine*

Virtual Lab *What is the life cycle of a simple plant?*

How are all plants alike?

Plants are found nearly everywhere on Earth. A tropical rain forest like this one is crowded with lush, green plants. When you look at a plant, what do you expect to see? Do all plants have green leaves? Do all plants produce flowers and seeds?

Science Journal Write three characteristics that you think all plants have in common.

Peter Adams /Getty Images

Start-Up Activities

Launch LAB

How do you use plants?

Plants are just about everywhere—in parks and gardens, by streams, on rocks, in houses, and even on dinner plates. Do you use plants for things other than food?

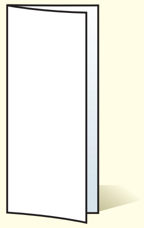
1. Brainstorm with two other classmates and make a list of everything that you use in a day that comes from plants.
2. Compare your list with those of other groups in your class.
3. Search through old magazines for images of the items on your list.
4. As a class, build a bulletin board display of the magazine images.
5. **Think Critically** In your Science Journal, list things that were made from plants 100 years or more ago but today are made from plastics, steel, or some other material.

Science Online — Preview this chapter's content and activities at bookb.msscience.com

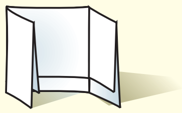
FOLDABLES™ Study Organizer

Plants Make the following Foldable to help identify what you already know, what you want to know, and what you learned about plants.

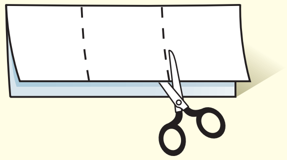
STEP 1 **Fold** a vertical sheet of paper from side to side. Make the front edge 1.25 cm shorter than the back edge.



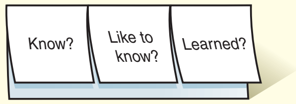
STEP 2 **Turn** lengthwise and fold into thirds.



STEP 3 **Unfold and cut** only the top layer along both folds to make three tabs.



STEP 4 **Label** each tab as shown.



Identify Questions Before you read the chapter, write what you already know about plants under the left tab of your Foldable, and write questions about what you'd like to know under the center tab. After you read the chapter, list what you learned under the right tab.

CONTENTS

Peter Adams /Getty Images

section 1

An Overview of Plants

as you read

What You'll Learn

- **Identify** characteristics common to all plants.
- **Explain** which plant adaptations make it possible for plants to survive on land.
- **Compare and contrast** vascular and nonvascular plants.

Why It's Important

Plants produce food and oxygen, which are required for life by most organisms on Earth.

Review Vocabulary
species: closely related organisms that share similar characteristics and can reproduce among themselves

New Vocabulary
- cuticle
- cellulose
- vascular plant
- nonvascular plant

What is a plant?

What is the most common sight you see when you walk along nature trails in parks like the one shown in **Figure 1?** Maybe you've taken off your shoes and walked barefoot on soft, cool grass. Perhaps you've climbed a tree to see what things look like from high in its branches. In each instance, plants surrounded you.

If you named all the plants that you know, you probably would include trees, flowers, vegetables, fruits, and field crops like wheat, rice, or corn. Between 260,000 and 300,000 plant species have been discovered and identified. Scientists think many more species are still to be found, mainly in tropical rain forests. Plants are important food sources to humans and other consumers. Without plants, most life on Earth as we know it would not be possible.

Plant Characteristics Plants range in size from microscopic water ferns to giant sequoia trees that are sometimes more than 100 m in height. Most have roots or rootlike structures that hold them in the ground or onto some other object like a rock or another plant. Plants are adapted to nearly every environment on Earth. Some grow in frigid, ice-bound polar regions and others grow in hot, dry deserts. All plants need water, but some plants cannot live unless they are submerged in either freshwater or salt water.

Figure 1 All plants are many-celled and nearly all contain chlorophyll. Grasses, trees, shrubs, mosses, and ferns are all plants.

Tom Stack & Assoc.

Plant Cells Like other living things, plants are made of cells. A plant cell has a cell membrane, a nucleus, and other cellular structures. In addition, plant cells have cell walls that provide structure and protection. Animal cells do not have cell walls.

Many plant cells contain the green pigment chlorophyll (KLOR uh fihl) so most plants are green. Plants need chlorophyll to make food using a process called photosynthesis. Chlorophyll is found in a cell structure called a chloroplast. Plant cells from green parts of the plant usually contain many chloroplasts.

Most plant cells have a large, membrane-bound structure called the central vacuole that takes up most of the space inside of the cell. This structure plays an important role in regulating the water content of the cell. Many substances are stored in the vacuole, including the pigments that make some flowers red, blue, or purple.

Origin and Evolution of Plants

Have plants always existed on land? The first plants that lived on land probably could survive only in damp areas. Their ancestors were probably ancient green algae that lived in the sea. Green algae are one-celled or many-celled organisms that use photosynthesis to make food. Today, plants and green algae have the same types of chlorophyll and carotenoids (kuh RAH tun oydz) in their cells. Carotenoids are red, yellow, or orange pigments that also are used for photosynthesis. These facts lead scientists to think that plants and green algae have a common ancestor.

Reading Check *How are plants and green algae alike?*

Fossil Record The fossil record for plants is not like that for animals. Most animals have bones or other hard parts that can fossilize. Plants usually decay before they become fossilized. The oldest fossil plants are about 420 million years old. **Figure 2** shows *Cooksonia*, a fossil of one of these plants. Other fossils of early plants are similar to the ancient green algae. Scientists hypothesize that some of these early plants evolved into the plants that exist today.

Cone-bearing plants, such as pines, probably evolved from a group of plants that grew about 350 million years ago. Fossils of these plants have been dated to about 300 million years ago. It is estimated that flowering plants did not exist until about 120 million years ago. However, the exact origin of flowering plants is not known.

Figure 2 This is a fossil of a plant named *Cooksonia.* These plants grew about 420 million years ago and were about 2.5 cm tall.

Life on Land

Life on land has some advantages for plants. More sunlight and carbon dioxide—needed for photosynthesis—are available on land than in water. During photosynthesis, plants give off oxygen. Long ago, as more and more plants adapted to life on land, the amount of oxygen in Earth's atmosphere increased. This was the beginning for organisms that depend on oxygen.

INTEGRATE History

Cellulose Plant cell walls are made mostly of cellulose. Anselme Payen, a French scientist, first isolated and identified the chemical composition of cellulose in 1838, while analyzing the chemical makeup of wood. Choose a type of wood and research to learn the uses of that wood. Make a classroom display of research results.

Adaptations to Land

What is life like for green algae, shown in **Figure 3,** as they float in a shallow pool? The water in the pool surrounds and supports them as the algae make their own food through the process of photosynthesis. Because materials can enter and leave through their cell membranes and cell walls, the algae cells have everything they need to survive as long as they have water.

If the pool begins to dry up, the algae are on damp mud and are no longer supported by water. As the soil becomes drier and drier, the algae will lose water too because water moves through their cell membranes and cell walls from where there is more water to where there is less water. Without enough water in their environment, the algae will die. Plants that live on land have adaptations that allow them to conserve water, as well as other differences that make it possible for survival.

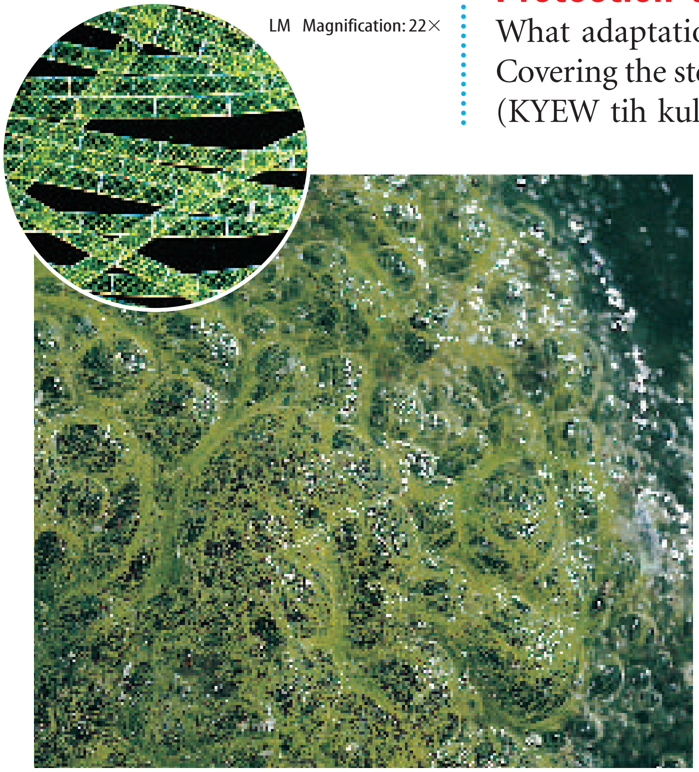


Figure 3 The alga *Spirogyra*, like all algae, must have water to survive. If the pool where it lives dries up, it will die.

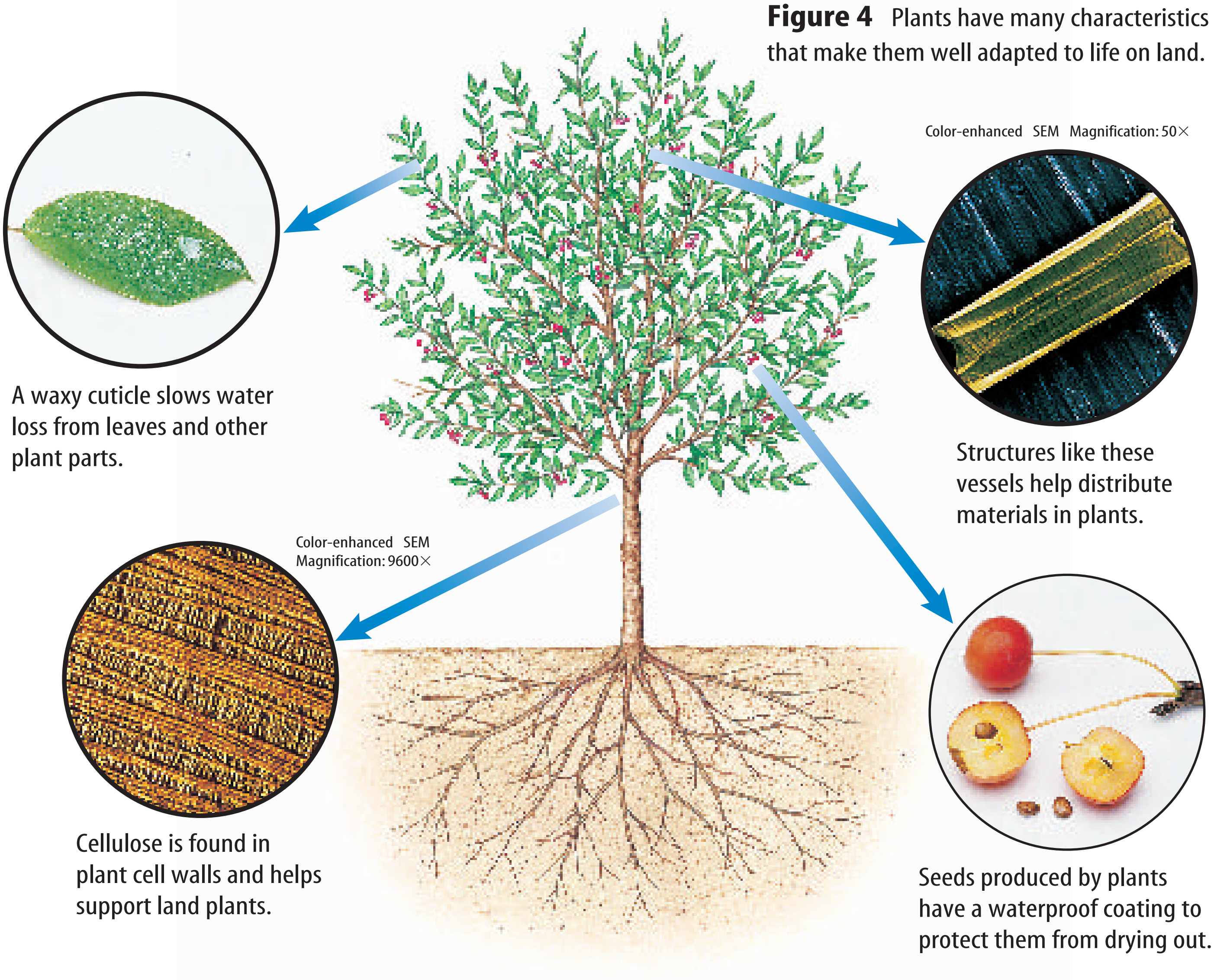
Protection and Support Water is important for plants. What adaptations would help a plant conserve water on land? Covering the stems, leaves, and flowers of many plants is a **cuticle** (KYEW tih kul)—a waxy, protective layer secreted by cells onto the surface of the plant. The cuticle slows the loss of water. The cuticle and other adaptations shown in **Figure 4** enable plants to survive on land.

Reading Check ***What is the function of a plant's cuticle?***

Supporting itself is another problem for a plant on land. Like all cells, plant cells have cell membranes, but they also have rigid cell walls outside the membrane. Cell walls contain **cellulose** (SEL yuh lohs), which is a chemical compound that plants can make out of sugar. Long chains of cellulose molecules form tangled fibers in plant cell walls. These fibers provide structure and support.

(t)Kim Taylor/Bruce Coleman, Inc., (b)William E. Ferguson

Figure 4 Plants have many characteristics that make them well adapted to life on land.



Other Cell Wall Substances Cells of some plants secrete other substances into the cellulose that make the cell wall even stronger. Trees, such as oaks and pines, could not grow without these strong cell walls. Wood from trees can be used for construction mostly because of strong cell walls.

Life on land means that each plant cell is not surrounded by water and dissolved nutrients that can move into the cell. Through adaptations, structures developed in many plants that distribute water, nutrients, and food to all plant cells. These structures also help provide support for the plant.

Reproduction Changes in reproduction were necessary if plants were to survive on land. The presence of water-resistant spores helped some plants reproduce successfully. Other plants adapted by producing water-resistant seeds in cones or in flowers that developed into fruits.

manita Pictures, (tr)Ken Eward/Photo Researchers, (bl)Photo Researchers, (br)Amanita Pictures

NATIONAL GEOGRAPHIC

VISUALIZING PLANT CLASSIFICATION

Figure 5

Scientists group plants as either vascular—those with water- and food-conducting cells in their stems—or nonvascular. Vascular plants are further divided into those that produce spores and those that make seeds.

(cs from top)Dan McCoy from Rainbow, Philip Dowell/DK Images, Kevin & Betty Collins/Visuals Unlimited, David Sieren/Visuals Unlimited, Steve Callaham/Visuals Unlimited, Gerald & Buff Corsi/Visuals Unlimited,

Mack Henley/Visuals Unlimited, Edward S. Ross, Douglas Peebles/CORBIS, Gerald & Buff Cor... Photos

Classification of Plants

The plant kingdom is classified into major groups called divisions. A division is the same as a phylum in other kingdoms. Another way to group plants is as vascular (VAS kyuh lur) or nonvascular plants, as illustrated in **Figure 5.** **Vascular plants** have tubelike structures that carry water, nutrients, and other substances throughout the plant. **Nonvascular plants** do not have these tubelike structures and use other ways to move water and substances.

Naming Plants Why do biologists call a pecan tree *Carya illinoiensis* and a white oak *Quercus alba?* They are using words that accurately name the plant. In the third century B.C., most plants were grouped as trees, shrubs, or herbs and placed into smaller groups by leaf characteristics. This simple system survived until late in the eighteenth century when a Swedish botanist, Carolus Linnaeus, developed a new system. His new system used many characteristics to classify a plant. He also developed a way to name plants called binomial nomenclature (bi NOH mee ul • NOH mun klay chur). Under this system, every plant species is given a unique two-word name like the names above for the pecan tree and white oak and for the two daisies in **Figure 6.**

Figure 6 Although these two plants are both called daisies, they are not the same species of plant. Using their binomial names helps eliminate the confusion that might come from using their common names.

section 1 review

Summary

What is a plant?

- All plant cells are surrounded by a cell wall.
- Many plant cells contain chlorophyll.

Origin and Evolution of Plants

- Ancestors of land plants were probably ancient green algae.

Adaptations to Land

- A waxy cuticle helps conserve water.
- Cellulose strengthens cell walls.

Classification of Plants

- The plant kingdom is divided into two groups—nonvascular plants and vascular plants.
- Vascular tissues transport nutrients.

Self Check

1. **List** the characteristics of plants.
2. **Compare and contrast** the characteristics of vascular and nonvascular plants.
3. **Identify** three adaptations that allow plants to survive on land.
4. **Explain** why binomial nomenclature is used to name plants.
5. **Thinking Critically** If you left a board lying on the grass for a few days, what would happen to the grass underneath the board? Why?

Applying Skills

6. **Form a hypothesis** about adaptations a land plant might undergo if it lived submerged in water.

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(t)Gail Jankus/Photo Researchers, (b)Michael P. Fogden/Bruce Coleman, Inc.

section 2

Seedless Plants

as you read

What You'll Learn

- **Distinguish** between characteristics of seedless nonvascular plants and seedless vascular plants.
- **Identify** the importance of some nonvascular and vascular plants.

Why It's Important

Seedless plants are among the first to grow in damaged or disturbed environments and help build soil for the growth of other plants.

Review Vocabulary
spore: waterproof reproductive cell

New Vocabulary
- rhizoid
- pioneer species

Figure 7 The seedless nonvascular plants include mosses, liverworts, and hornworts.

Seedless Nonvascular Plants

If you were asked to name the parts of a plant, you probably would list roots, stems, leaves, and flowers. You also might know that many plants grow from seeds. However, some plants, called nonvascular plants, don't grow from seeds and they do not have all of these parts. **Figure 7** shows some common types of nonvascular plants.

Nonvascular plants are usually just a few cells thick and only 2 cm to 5 cm in height. Most have stalks that look like stems and green, leaflike growths. Instead of roots, threadlike structures called **rhizoids** (RI zoydz) anchor them where they grow. Most nonvascular plants grow in places that are damp. Water is absorbed and distributed directly through their cell membranes and cell walls. Nonvascular plants also do not have flowers or cones that produce seeds. They reproduce by spores. Mosses, liverworts, and hornworts are examples of nonvascular plants.

Mosses Most nonvascular plants are classified as mosses, like the ones in **Figure 7.** They have green, leaflike growths arranged around a central stalk. Their rhizoids are made of many cells. Sometimes stalks with caps grow from moss plants. Reproductive cells called spores are produced in the caps of these stalks. Mosses often grow on tree trunks and rocks or the ground. Although they commonly are found in damp areas, some are adapted to living in deserts.

Close-up of moss plants | Close-up of a liverwort | Close-up of a hornwort

(l)Larry West/Bruce Coleman, Inc., (c)Scott Camazine/Photo Researchers, (r)Kathy Merrifield/P

Figure 8 Mosses can grow in the thin layer of soil that covers these rocks.

Liverworts In the ninth century, liverworts were thought to be useful in treating diseases of the liver. The suffix *-wort* means "herb," so the word *liverwort* means "herb for the liver." Liverworts are rootless plants with flattened, leaflike bodies, as shown in **Figure 7.** They usually have one-celled rhizoids.

Hornworts Most hornworts are less than 2.5 cm in diameter and have a flattened body like liverworts, as shown in **Figure 7.** Unlike other nonvascular plants, almost all hornworts have only one chloroplast in each of their cells. Hornworts get their name from their spore-producing structures, which look like tiny horns of cattle.

INTEGRATE Environment

Nonvascular Plants and the Environment Mosses and liverworts are important in the ecology of many areas. Although they require moist conditions to grow and reproduce, many of them can withstand long, dry periods. They can grow in thin soil and in soils where other plants could not grow, as shown in **Figure 8.**

Spores of mosses and liverworts are carried by the wind. They will grow into plants if growing conditions are right. Mosses often are among the first plants to grow in new or disturbed environments, such as lava fields or after a forest fire. Organisms that are the first to grow in new or disturbed areas are called **pioneer species.** As pioneer plants grow and die, decaying material builds up. This, along with the slow breakdown of rocks, builds soil. When enough soil has formed, other organisms can move into the area.

Reading Check ***Why are pioneer plant species important in disturbed environments?***

Mini LAB

Measuring Water Absorption by a Moss

Procedure

1. Place a few teaspoons of ***Sphagnum*** **moss** on a piece of **cheesecloth.** Gather the corners of the cloth and twist, then tie them securely to form a ball.
2. Weigh the ball.
3. Put 200 mL of **water** in a **container** and add the ball.
4. After 15 min, remove the ball and drain the excess water into the container.
5. Weigh the ball and measure the amount of water left in the container.
6. Wash your hands after handling the moss.

Analysis

In your **Science Journal,** calculate how much water was absorbed by the *Sphagnum* moss.

Michael P. Gadomski/Photo Researchers

Science Online

Topic: Medicinal Plants

Visit bookb.msscience.com for Web links to information about plants used as medicines.

Activity In your Science Journal, list four medicinal plants and their uses.

Seedless Vascular Plants

The fern in **Figure 9** is growing next to some moss plants. Ferns and mosses are alike in one way. Both reproduce by spores instead of seeds. However, ferns are different from mosses because they have vascular tissue. The vascular tissue in seedless vascular plants, like ferns, is made up of long, tubelike cells. These cells carry water, minerals, and food to cells throughout the plant. Why is vascular tissue an advantage to a plant? Nonvascular plants like the moss are usually only a few cells thick. Each cell absorbs water directly from its environment. As a result, these plants cannot grow large. Vascular plants, on the other hand, can grow bigger and thicker because the vascular tissue distributes water and nutrients to all plant cells.

Applying Science

What is the value of rain forests?

Throughout history, cultures have used plants for medicines. Some cultures used willow bark to cure headaches. Willow bark contains salicylates (suh LIH suh layts), the main ingredient in aspirin. Heart problems were treated with foxglove, which is the main source of digitalis (dih juh TAH lus), a drug prescribed for heart problems. Have all medicinal plants been identified?

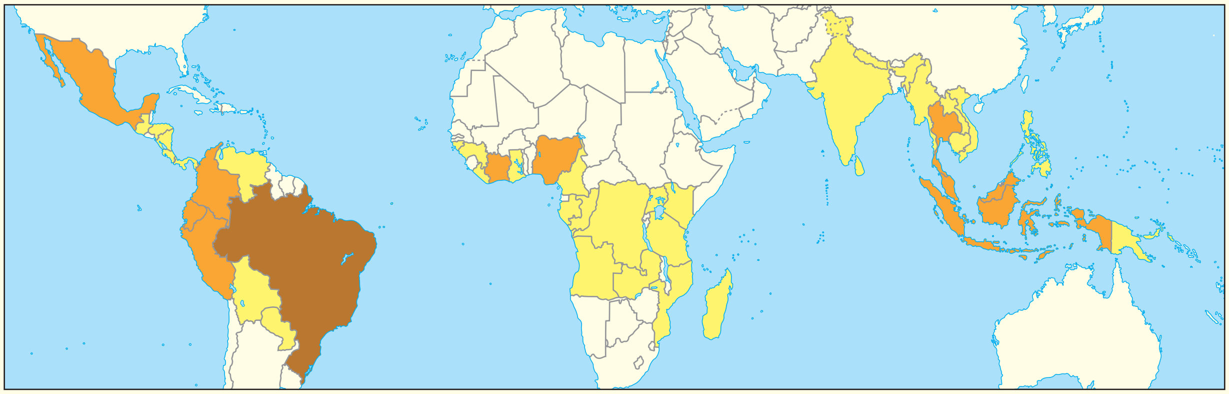
Identifying the Problem

Tropical rain forests have the largest variety of organisms on Earth. Many plant species are still unknown. These forests are being destroyed rapidly. The map below shows the rate of destruction of the rain forests. Some scientists estimate that most tropical rain forests will be destroyed in 30 years.

Solving the Problem

1. What country has the most rain forest destroyed each year?
2. Where can scientists go to study rain forest plants before the plants are destroyed?
3. Predict how the destruction of rain forests might affect research on new drugs from plants.

Deforested annually (km^2)
- more than 15,000
- 2,000 to 14,800
- 100 to 1,900



Types of Seedless Vascular Plants

Besides ferns, seedless vascular plants include ground pines, spike mosses, and horsetails. About 1,000 species of ground pines, spike mosses, and horsetails are known to exist. Ferns are more abundant, with at least 12,000 known species. Many species of seedless vascular plants are known only from fossils. They flourished during the warm, moist period 360 million to 286 million years ago. Fossil records show that some horsetails grew 15 m tall, unlike modern species, which grow only 1 m to 2 m tall.

Figure 9 The mosses and ferns pictured here are seedless plants. **Explain** *why the fern can grow taller than the moss.*

Ferns The largest group of seedless vascular plants is the ferns. They include many different forms, as shown in **Figure 10.** They have stems, leaves, and roots. Fern leaves are called fronds. Ferns produce spores in structures that usually are found on the underside of their fronds. Thousands of species of ferns now grow on Earth, but many more existed long ago. From clues left in rock layers, scientists infer that about 360 million years ago much of Earth was tropical. Steamy swamps covered large areas. The tallest plants were species of ferns. The ancient ferns grew as tall as 25 m—as tall as the tallest fern species alive today. Most modern tree ferns are about 3 m to 5 m in height and grow in tropical regions of the world.

Figure 10 Ferns come in many different shapes and sizes.

The sword fern has a typical fern shape. Spores are produced in structures on the back of the frond.

This fern grows on other plants, not in the soil.
Infer *why it's called the staghorn fern.*

Tree ferns, like this one in Hawaii, grow in tropical areas.

(t)Fa… …eh… CONTENTS Sol… …uce Coleman, Inc., (bc)R. Van Nostrand/Photo Researchers, (br) Inga Spence/Visuals Unlimited

Club Mosses Ground pines and spike mosses are groups of plants that often are called club mosses. They are related more closely to ferns than to mosses. These seedless vascular plants have needle-like leaves. Spores are produced at the end of the stems in structures that look like tiny pine cones. Ground pines, shown in **Figure 11,** are found from arctic regions to the tropics, but rarely in large numbers. In some areas, they are endangered because they have been over collected to make wreaths and other decorations.

(t)Joy Spurr/Bruce Coleman, Inc., (b)W.H. Black/Bruce Coleman, Inc

Reading Check *Where are spores in club mosses produced?*

Figure 11 Photographers once used the dry, flammable spores of club mosses as flash powder. It burned rapidly and produced the light that was needed to take photographs.

Spike mosses resemble ground pines. One species of spike moss, the resurrection plant, is adapted to desert conditions. When water is scarce, the plant curls up and seems dead. When water becomes available, the resurrection plant unfurls its green leaves and begins making food again. The plant can repeat this process whenever necessary.

Horsetails The stem structure of horsetails is unique among the vascular plants. The stem is jointed and has a hollow center surrounded by a ring of vascular tissue. At each joint, leaves grow out from around the stem. In **Figure 12,** you can see these joints. If you pull on a horsetail stem, it will pop apart in sections. Like the club mosses, spores from horsetails are produced in a conelike structure at the tips of some stems. The stems of the horsetails contain silica, a gritty substance found in sand. For centuries, horsetails have been used for polishing objects, sharpening tools, and scouring cooking utensils. Another common name for horsetails is scouring rush.

Figure 12 Most horsetails grow in damp areas and are less than 1 m tall.
Identify *where spores would be produced on this plant.*

Importance of Seedless Plants

When many ancient seedless plants died, they became submerged in water and mud before they decomposed. As this plant material built up, it became compacted and compressed and eventually turned into coal—a process that took millions of years.

Today, a similar process is taking place in bogs, which are poorly drained areas of land that contain decaying plants. The plants in bogs are mostly seedless plants like mosses and ferns.

Peat When bog plants die, the waterlogged soil slows the decay process. Over time, these decaying plants are compressed into a substance called peat. Peat, which forms from the remains of sphagnum moss, is mined from bogs to use as a low-cost fuel in places such as Ireland and Russia, as shown in **Figure 13.** Peat supplies about one-third of Ireland's energy requirements. Scientists hypothesize that over time, if additional layers of soil bury, compact, and compress the peat, it will become coal.

Figure 13 Peat is cut from bogs and used for a fuel in some parts of Europe.

Uses of Seedless Vascular Plants Many people keep ferns as houseplants. Ferns also are sold widely as landscape plants for shady areas. Peat and sphagnum mosses also are used for gardening. Peat is an excellent soil conditioner, and sphagnum moss often is used to line hanging baskets. Ferns also are used as weaving material for basketry.

Although most mosses are not used for food, parts of many other seedless vascular plants can be eaten. The rhizomes and young fronds of some ferns are edible. The dried stems of one type of horsetail can be ground into flour. Seedless plants have been used as folk medicines for hundreds of years. For example, ferns have been used to treat bee stings, burns, fevers, and even dandruff.

section 2 review

Summary

Seedless Nonvascular Plants

- Seedless nonvascular plants include mosses, liverworts, and hornworts.
- They are usually only a few cells thick and no more than a few centimeters tall.
- They produce spores rather than seeds.

Seedless Vascular Plants

- Seedless vascular plants include ferns, club mosses, and horsetails.
- Vascular plants grow taller and can live farther from water than nonvascular plants.

Importance of Seedless Plants

- Nonvascular plants help build new soil.
- Coal deposits formed from ancient seedless plants that were buried in water and mud before they began to decay.

Self Check

1. **Compare and contrast** the characteristics of mosses and ferns.
2. **Explain** what fossil records tell about seedless plants that lived on Earth long ago.
3. **Identify** growing conditions in which you would expect to find pioneer plants such as mosses and liverworts.
4. **Summarize** the functions of vascular tissues.
5. **Think Critically** The electricity that you use every day might be produced by burning coal. What is the connection between electricity production and seedless vascular plants?

Applying Math

6. **Use Fractions** Approximately 8,000 species of liverworts and 9,000 species of mosses exist today. Estimate what fraction of these seedless nonvascular plants are mosses.

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CONTENTS

Farrell Grehan/Photo Researchers

section 3 Seed Plants

as you read

What You'll Learn

- **Identify** the characteristics of seed plants.
- **Explain** the structures and functions of roots, stems, and leaves.
- **Describe** the main characteristics and importance of gymnosperms and angiosperms.
- **Compare** similarities and differences between monocots and dicots.

Why It's Important

Humans depend on seed plants for food, clothing, and shelter.

Review Vocabulary

seed: plant embryo and food supply in a protective coating

New Vocabulary

- stomata
- guard cell
- xylem
- phloem
- cambium
- gymnosperm
- angiosperm
- monocot
- dicot

Characteristics of Seed Plants

What foods from plants have you eaten today? Apples? Potatoes? Carrots? Peanut butter and jelly sandwiches? All of these foods and more come from seed plants.

Most of the plants you are familiar with are seed plants. Most seed plants have leaves, stems, roots, and vascular tissue. They also produce seeds, which usually contain an embryo and stored food. The stored food is the source of energy for the embryo's early growth as it develops into a plant. Most of the plant species that have been identified in the world today are seed plants. The seed plants generally are classified into two major groups—gymnosperms (JIHM nuh spurmz) and angiosperms (AN jee uh spurmz).

Leaves Most seed plants have leaves. Leaves are the organs of the plant where the food-making process—photosynthesis—usually occurs. Leaves come in many shapes, sizes, and colors. Examine the structure of a typical leaf, shown in **Figure 14.**

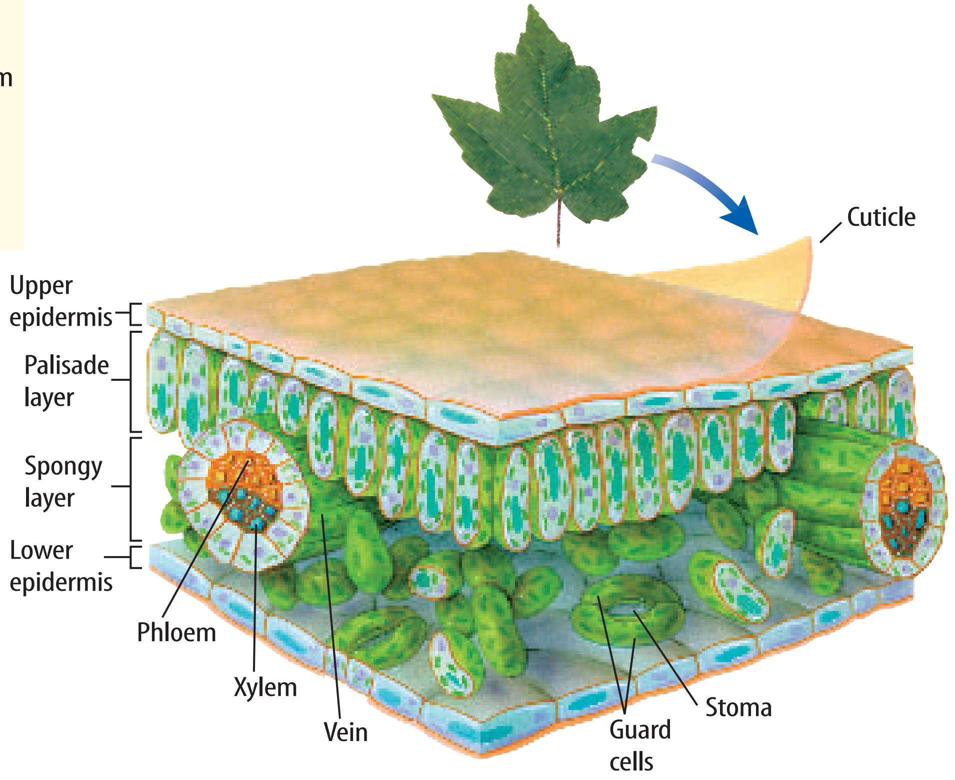


Figure 14 The structure of a typical leaf is adapted for photosynthesis.
Explain *why cells in the palisade layer have more chloroplasts than cells in the spongy layer.*

Leaf Cell Layers A typical leaf is made of several different layers of cells. On the upper and lower surfaces of a leaf is a thin layer of cells called the epidermis, which covers and protects the leaf. A waxy cuticle coats the epidermis of some leaves. Most leaves have small openings in the epidermis called **stomata** (STOH muh tuh) (singular, *stoma*). Stomata allow carbon dioxide, water, and oxygen to enter into and exit from a leaf. Each stoma is surrounded by two **guard cells** that open and close it.

Just below the upper epidermis is the palisade layer. It consists of closely packed, long, narrow cells that usually contain many chloroplasts. Most of the food produced by plants is made in the palisade cells. Between the palisade layer and the lower epidermis is the spongy layer. It is a layer of loosely arranged cells separated by air spaces. In a leaf, veins containing vascular tissue are found in the spongy layer.

Stems The trunk of a tree is really the stem of the tree. Stems usually are located above ground and support the branches, leaves, and reproductive structures. Materials move between leaves and roots through the vascular tissue in the stem. Stems also can have other functions, as shown in **Figure 15.**

Plant stems are either herbaceous (hur BAY shus) or woody. Herbaceous stems usually are soft and green, like the stems of a tulip, while trees and shrubs have hard, rigid, woody stems. Lumber comes from woody stems.

Mini LAB

Observing Water Moving in a Plant

Procedure

1. Into a **clear container** pour **water** to a depth of 1.5 cm. Add 25 drops of **red food coloring** to the water.
2. Put the root end of a **green onion** into the container. Do not cut the onion in any way. Wash your hands.
3. The next day, examine the outside of the onion. Peel off the onion's layers and examine them. **WARNING:** *Do not eat the onion.*

Analysis

In your **Science Journal,** infer how the location of red color inside the onion might be related to vascular tissue.

Try at Home

Figure 15 Some plants have stems with special functions.

These potatoes are stems that grow underground and store food for the plant.

The stems of this cactus store water and can carry on photosynthesis.

Some stems of this grape plant help it climb on other plants.

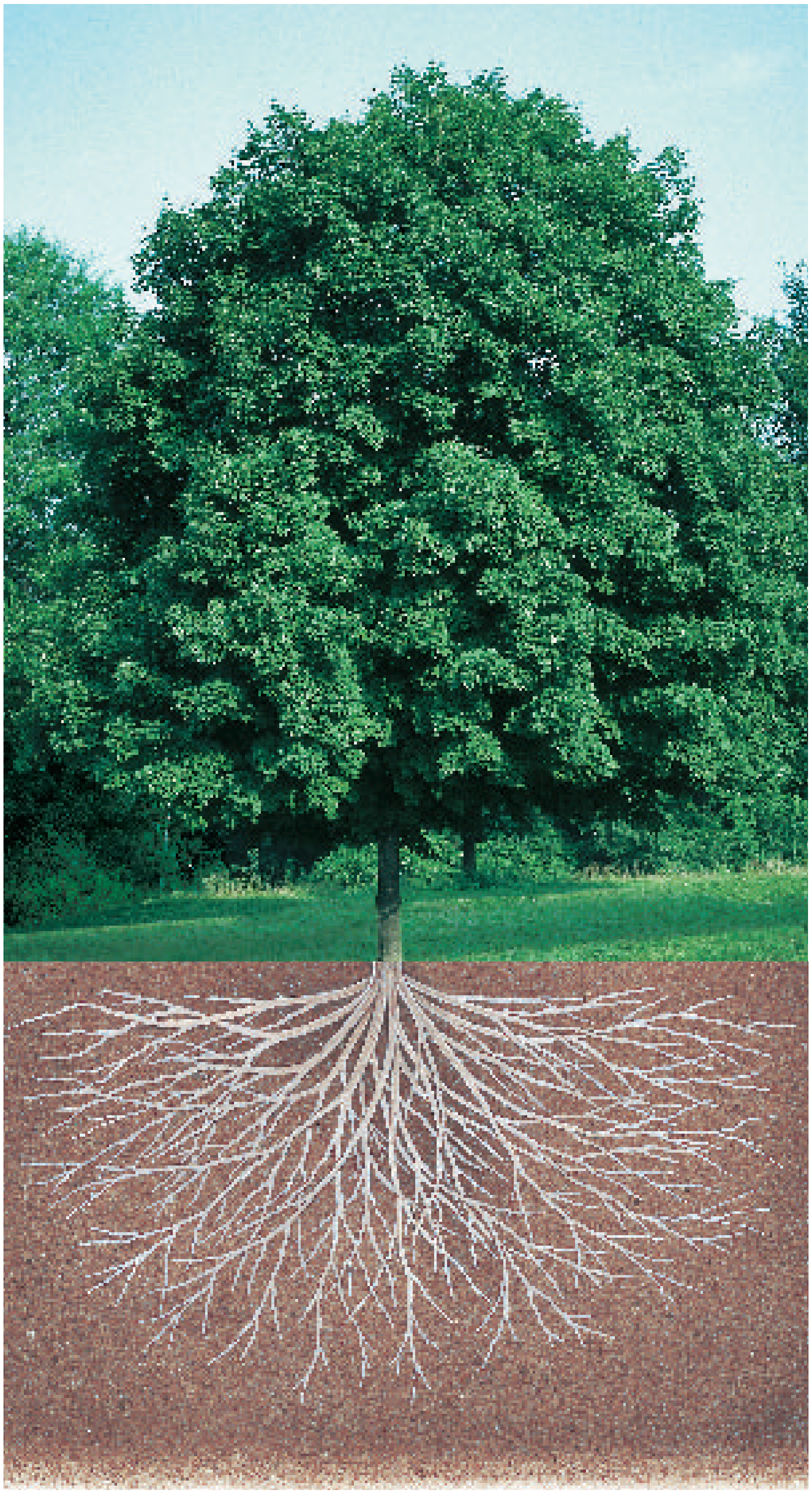


Figure 16 The root system of a tree can be as long as the tree can be tall.
Infer *why the root system of a tree would need to be so large.*

Roots Imagine a lone tree growing on top of a hill. What is the largest part of this plant? Maybe you guessed the trunk or the branches. Did you consider the roots, like those shown in **Figure 16?** The root systems of most plants are as large or larger than the aboveground stems and leaves.

Roots are important to plants. Water and other substances enter a plant through its roots. Roots have vascular tissue in which water and dissolved substances move from the soil through the stems to the leaves. Roots also act as anchors, preventing plants from being blown away by wind or washed away by moving water. Underground root systems support other plant parts that are aboveground—the stem, branches, and leaves of a tree. Sometimes, part of or all of the roots are aboveground, too.

Roots can store food. When you eat carrots or beets, you eat roots that contain stored food. Plants that continue growing from one year to the next use this stored food to begin new growth in the spring. Plants that grow in dry areas often have roots that store water.

Root tissues also can perform functions such as absorbing oxygen that is used in the process of respiration. Because water does not contain as much oxygen as air does, plants that grow with their roots in water might not be able to absorb enough oxygen. Some swamp plants have roots that grow partially out of the water and take in oxygen from the air. In order to perform all these functions, the root systems of plants must be large.

Reading Check *What are several functions of roots in plants?*

Vascular Tissue Three tissues usually make up the vascular system in a seed plant. **Xylem** (ZI lum) tissue is made up of hollow, tubular cells that are stacked one on top of the other to form a structure called a vessel. These vessels transport water and dissolved substances from the roots throughout the plant. The thick cell walls of xylem are also important because they help support the plant.

Phloem (FLOH em) is a plant tissue also made up of tubular cells that are stacked to form structures called tubes. Tubes are different from vessels. Phloem tubes move food from where it is made to other parts of the plant where it is used or stored.

In some plants, a cambium is between xylem and phloem. **Cambium** (KAM bee um) is a tissue that produces most of the new xylem and phloem cells. The growth of this new xylem and phloem increases the thickness of stems and roots. All three tissues are illustrated in **Figure 17.**

INTEGRATE Health

Vascular Systems Plants have vascular tissue, and you have a vascular system. Your vascular system transports oxygen, food, and wastes through blood vessels. Instead of xylem and phloem, your blood vessels include veins and arteries. In your Science Journal write a paragraph describing the difference between veins and arteries.

Figure 17 The vascular tissue of some seed plants includes xylem, phloem, and cambium.
Identify *which of these tissues transports food throughout the plant.*

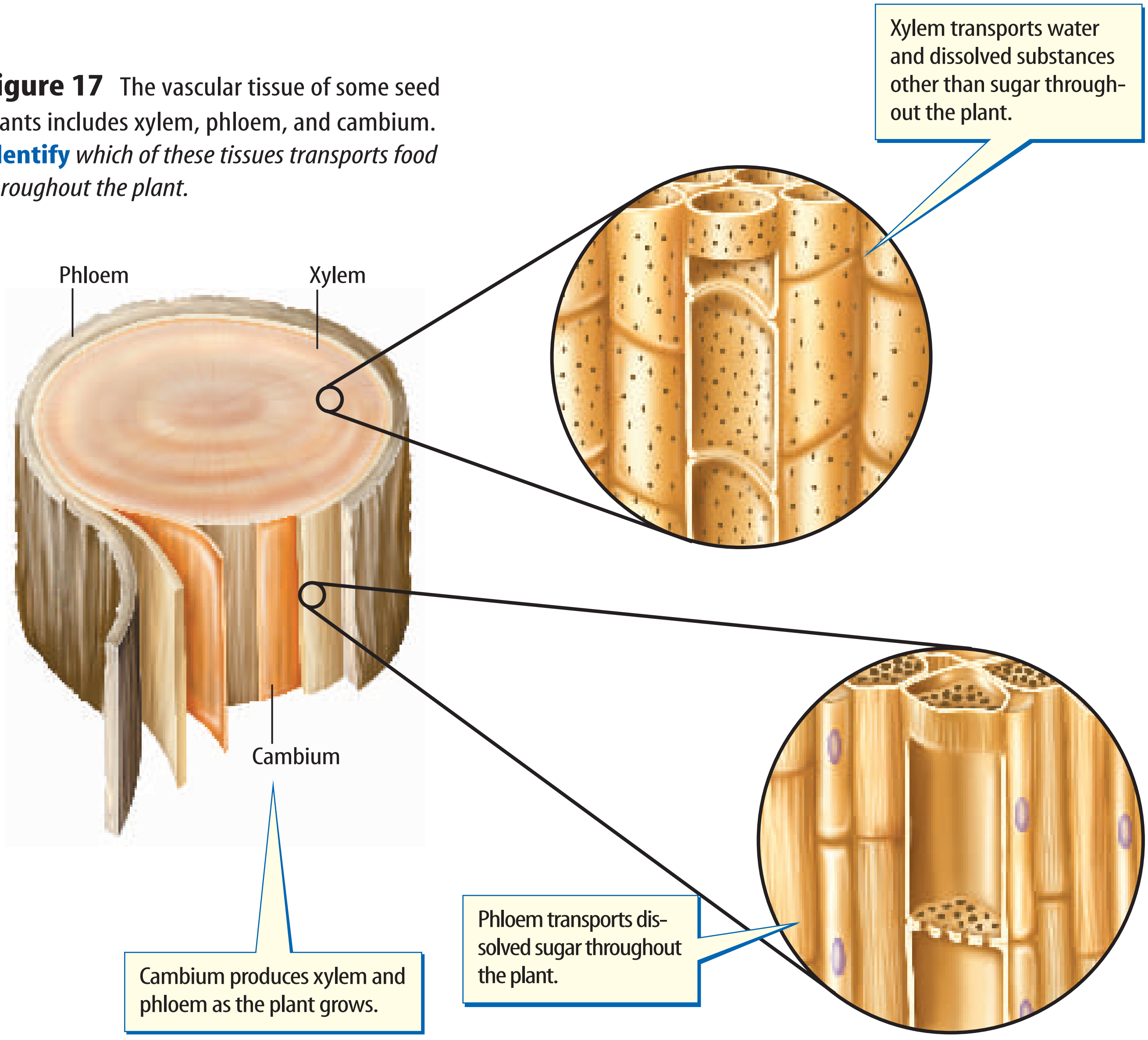


Figure 18 The gymnosperms include four divisions of plants.

About 100 species of cycads exist today. Only one genus is native to the United States.

Conifers are the largest, most diverse division. Most conifers are evergreen plants, such as this ponderosa pine (above).

More than half of the 70 species of gnetophytes, such as this joint fir, are in one genus.

The ginkgoes are represented by one living species. Ginkgoes lose their leaves in the fall.
Explain *how this is different from most gymnosperms.*

Gymnosperms

The oldest trees alive are gymnosperms. A bristlecone pine tree in the White Mountains of eastern California is estimated to be 4,900 years old. **Gymnosperms** are vascular plants that produce seeds that are not protected by fruit. The word *gymnosperm* comes from the Greek language and means "naked seed." Another characteristic of gymnosperms is that they do not have flowers. Leaves of most gymnosperms are needlelike or scalelike. Many gymnosperms are called evergreens because some green leaves always remain on their branches.

Four divisions of plants—conifers, cycads, ginkgoes, and gnetophytes (NE tuh fites)—are classified as gymnosperms. **Figure 18** shows examples of the four divisions. You are probably most familiar with the division Coniferophyta (kuh NIH fur uh fi tuh), the conifers. Pines, firs, spruces, redwoods, and junipers belong to this division. It contains the greatest number of gymnosperm species. All conifers produce two types of cones—male and female. Both types usually are found on the same plant. Cones are the reproductive structures of conifers. Seeds develop on the female cone but not on the male cone.

Reading Check *What is the importance of cones to gymnosperms?*

Angiosperms

When people are asked to name a plant, most name an angiosperm. An **angiosperm** is a vascular plant that flowers and produces fruits with one or more seeds, such as the peaches shown in **Figure 19.** The fruit develops from a part or parts of one or more flowers. Angiosperms are familiar plants no matter where you live. They grow in parks, fields, forests, jungles, deserts, freshwater, salt water, and in the cracks of sidewalks. You might see them dangling from wires or other plants, and one species of orchid even grows underground. Angiosperms make up the plant division Anthophyta (AN thoh fi tuh). More than half of the known plant species belong to this division.

Flowers The flowers of angiosperms vary in size, shape, and color. Duckweed, an aquatic plant, has a flower that is only 0.1 mm long. A plant in Indonesia has a flower that is nearly 1 m in diameter and can weigh 9 kg. Nearly every color can be found in some flower, although some people would not include black. Multicolored flowers are common. Some plants have flowers that are not recognized easily as flowers, such as the flowers of ash trees, shown below.

Some flower parts develop into a fruit. Most fruits contain seeds, like an apple, or have seeds on their surface, like a strawberry. If you think all fruits are juicy and sweet, there are some that are not. The fruit of the vanilla orchid, as shown to the right, contains seeds and is dry.

Angiosperms are divided into two groups—the monocots and the dicots—shortened forms of the words *monocotyledon* (mah nuh kah tuh LEE dun) and *dicotyledon* (di kah tuh LEE dun).

Figure 19 Angiosperms have a wide variety of flowers and fruits.

The fruit of the vanilla orchid is the source of vanilla flavoring.

The flowers and fruit of a peach tree are typical of many angiosperms.

Ash flowers are not large and colorful. Their fruits are small and dry.

CONTENTS

Monocots and Dicots A cotyledon is part of a seed often used for food storage. The prefix *mono* means "one," and *di* means "two." Therefore, **monocots** have one cotyledon inside their seeds and **dicots** have two. The flowers, leaves, and stems of monocots and dicots are shown in **Figure 20.**

Many important foods come from monocots, including corn, rice, wheat, and barley. If you eat bananas, pineapple, or dates, you are eating fruit from monocots. Lilies and orchids also are monocots.

Dicots also produce familiar foods such as peanuts, green beans, peas, apples, and oranges. You might have rested in the shade of a dicot tree. Most shade trees, such as maple, oak, and elm, are dicots.

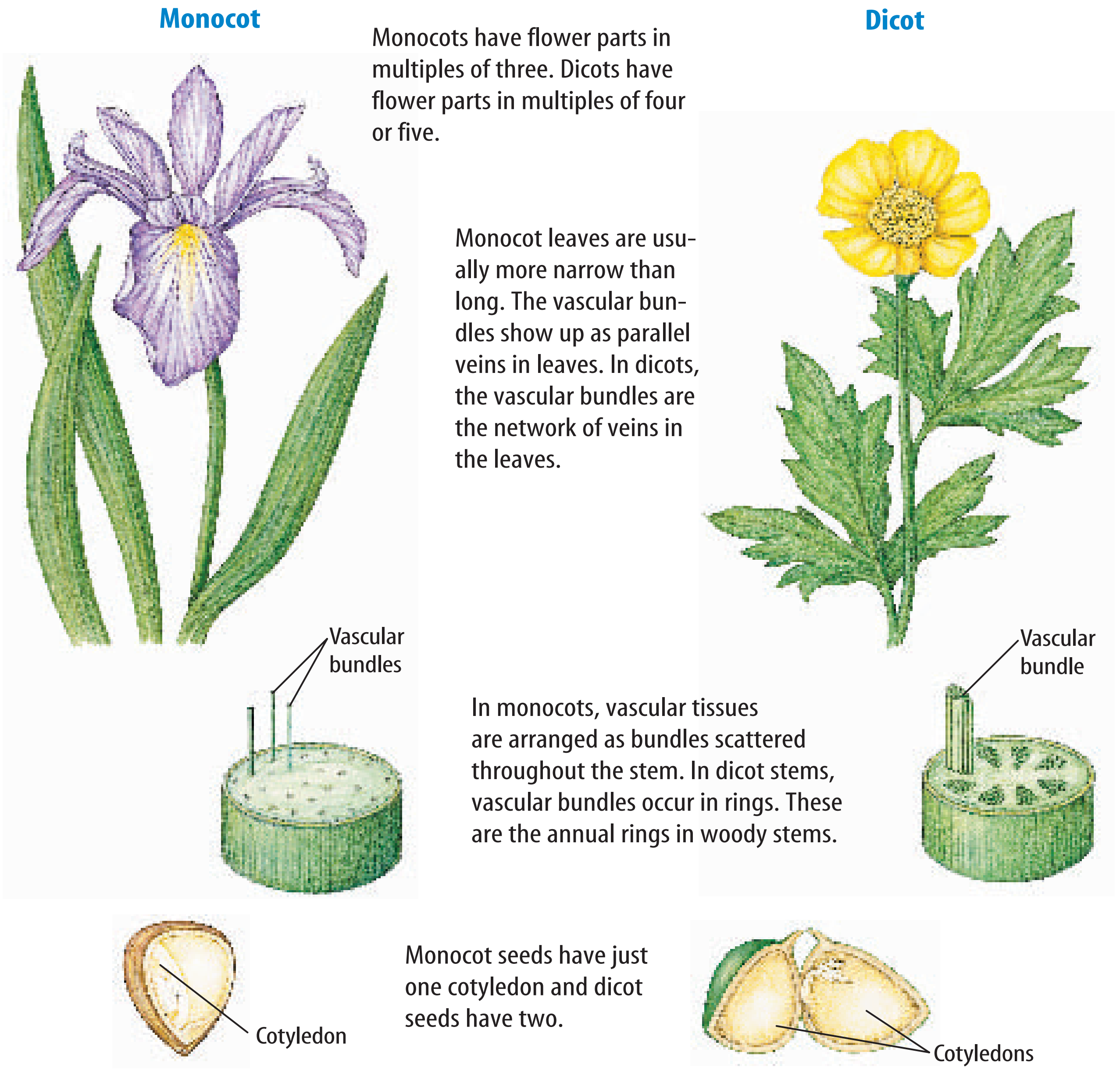


Figure 20 By observing a monocot and a dicot, you can determine their plant characteristics.

Petunias

Parsley

Pecan tree

Life Cycles of Angiosperms Flowering plants vary greatly in appearance. Their life cycles are as varied as the kinds of plants, as shown in **Figure 21.** Some angiosperms grow from seeds to mature plants with their own seeds in less than a month. The life cycles of other plants can take as long as a century. If a plant's life cycle is completed within one year, it is called an annual. These plants must be grown from seeds each year.

Plants called biennials (bi EH nee ulz) complete their life cycles within two years. Biennials such as parsley store a large amount of food in an underground root or stem for growth in the second year. Biennials produce flowers and seeds only during the second year of growth. Angiosperms that take more than two years to grow to maturity are called perennials. Herbaceous perennials such as peonies appear to die each winter but grow and produce flowers each spring. Woody perennials such as fruit trees produce flowers and fruits on stems that survive for many years.

Figure 21 Life cycles of angiosperms include annuals, biennials, and perennials. Petunias, which are annuals, complete their life cycle in one year. Parsley plants, which are biennials, do not produce flowers and seeds the first year. Perennials, such as the pecan tree, flower and produce fruits year after year.

Importance of Seed Plants

What would a day at school be like without seed plants? One of the first things you'd notice is the lack of paper and books. Paper is made from wood pulp that comes from trees, which are seed plants. Are the desks and chairs at your school made of wood? They would need to be made of something else if no seed plants existed. Clothing that is made from cotton would not exist because cotton comes from seed plants. At lunchtime, you would have trouble finding something to eat. Bread, fruits, and potato chips all come from seed plants. Milk, hamburgers, and hot dogs all come from animals that eat seed plants. Unless you like to eat plants such as mosses and ferns, you'd go hungry. Without seed plants, your day at school would be different.

Science Online

Topic: Renewable Resources
Visit bookb.msscience.com for Web links to information and recent news or magazine articles about the timber industry's efforts to replant trees.

Activity List in your Science Journal the species of trees that are planted and some of their uses.

Table 1 Some Products of Seed Plants

From Gymnosperms		From Angiosperms	
lumber, paper, soap, varnish, paints, waxes, perfumes, edible pine nuts, medicines		foods, sugar, chocolate, cotton cloth, linen, rubber, vegetable oils, perfumes, medicines, cinnamon, flavorings, dyes, lumber	

Products of Seed Plants Conifers are the most economically important gymnosperms. Most wood used for construction and for paper production comes from conifers. Resin, a waxy substance secreted by conifers, is used to make chemicals found in soap, paint, varnish, and some medicines.

The most economically important plants on Earth are the angiosperms. They form the basis of the diets of most animals. Angiosperms were the first plants that humans grew. They included grains, such as barley and wheat, and legumes, such as peas and lentils. Angiosperms are also the source of many of the fibers used in clothing. Besides cotton, linen fabrics come from plant fibers. **Table 1** shows just a few of the products of angiosperms and gymnosperms.

section 3 review

Summary

Characteristics of Seed Plants

- Leaves are organs in which photosynthesis takes place.
- Stems support leaves and branches and contain vascular tissues.
- Roots absorb water and nutrients from soil.

Gymnosperms

- Gymnosperms do not have flowers and produce seeds that are not protected by a fruit.

Angiosperms

- Angiosperms produce flowers that develop into a fruit with seeds.

Importance of Seed Plants

- The diets of most animals are based on angiosperms.

Self Check

1. **List** four characteristics common to all seed plants.
2. **Compare and contrast** the characteristics of gymnosperms and angiosperms.
3. **Classify** a flower with five petals as a monocot or a dicot.
4. **Explain** why the root system might be the largest part of a plant.
5. **Think Critically** The cuticle and epidermis of leaves are transparent. If they weren't, what might be the result?

Applying Skills

6. **Form a hypothesis** about what substance or substances are produced in palisade cells but not in xylem cells.

Science Online bookb.msscience.com/self_check_quiz
CONTENTS

LAB

Identifying Conifers

How can you tell a pine from a spruce or a cedar from a juniper? One way is to observe their leaves. The leaves of most conifers are either needlelike—shaped like needles—or scale-like—shaped like the scales on a fish. Examine and identify some conifer branches using the key to the right.

Real-World Question

How can leaves be used to classify conifers?

Goals

- **Identify** the difference between needlelike and scalelike leaves.
- **Classify** conifers according to their leaves.

Materials

short branches of the following conifers:

pine	Douglas fir	redwood
cedar	hemlock	arborvitae
spruce	fir	juniper

**illustrations of the conifers above*

**Alternate materials*

Safety Precautions

Wash your hands after handling leaves.

Procedure

1. **Observe** the leaves or illustrations of each conifer, then use the key to identify it.
2. **Write** the number and name of each conifer you identify in your Science Journal.

Conclude and Apply

1. **Name** two traits of hemlock leaves.
2. **Compare and contrast** pine and cedar leaves.

Key to Classifying Conifer Leaves

1. All leaves are needlelike.
   a. yes, go to 2
   b. no, go to 8
2. Needles are in clusters.
   a. yes, go to 3
   b. no, go to 4
3. Clusters contain two, three, or five needles.
   a. yes, pine
   b. no, cedar
4. Needles grow on all sides of the stem.
   a. yes, go to 5
   b. no, go to 7
5. Needles grow from a woody peg.
   a. yes, spruce
   b. no, go to 6
6. Needles appear to grow from the branch.
   a. yes, Douglas fir
   b. no, hemlock
7. Most of the needles grow upward.
   a. yes, fir
   b. no, redwood
8. All the leaves are scalelike but not prickly.
   a. yes, arborvitae
   b. no, juniper

Communicating Your Data

Use the key above to identify conifers growing on your school grounds. Draw and label a map that locates these conifers. Post the map in your school. **For more help, refer to the Science Skill Handbook.**

LAB

Use the Internet

Plants as Medicine

Goals

- **Identify** two plants that can be used as a treatment for illness or as a supplement to support good health.
- **Research** the cultural and historical use of each of the two selected plants as medical treatments.
- **Review** multiple sources to understand the effectiveness of each of the two selected plants as a medical treatment.
- **Compare and contrast** the research and form a hypothesis about the medicinal effectiveness of each of the two plants.

Data Source

Science Online

Visit bookb.msscience.com/internet_lab for more information about plants that can be used for maintaining good health and for data collected by other students.

Real-World Question

You may have read about using peppermint to relieve an upset stomach, or taking *Echinacea* to boost your immune system and fight off illness. But did you know that pioneers brewed a cough medicine from lemon mint? In this lab, you will explore plants and their historical use in treating illness, and the benefits and risks associated with using plants as medicine. How are plants used in maintaining good health?

Echinacea

Make a Plan

1. Search for information about plants that are used as medicine and identify two plants to investigate.
2. **Research** how these plants are currently recommended for use as medicine or to promote good health. Find out how each has been used historically.
3. **Explore** how other cultures used these plants as a medicine.

Mentha

Using Scientific Methods

Follow Your Plan

1. Make sure your teacher approves your plan before you start.
2. **Record** data you collect about each plant in your Science Journal.

Analyze Your Data

1. **Write** a description of how different cultures have used each plant as medicine.
2. How have the plants you investigated been used as medicine historically?
3. **Record** all the uses suggested by different sources for each plant.
4. **Record** the side effects of using each plant as a treatment.

Conclude and Apply

1. After conducting your research, what do you think are the benefits and drawbacks of using these plants as alternative medicines?
2. **Describe** any conflicting information about using each of these plants as medicine.
3. Based on your analysis, would you recommend the use of each of these two plants to treat illness or promote good health? Why or why not?
4. What would you say to someone who was thinking about using any plant-based, over-the-counter, herbal supplement?

Monarda

Communicating Your Data

Find this lab using the link below. Post your data for the two plants you investigated in the tables provided. **Compare** your data to those of other students. Review data that other students have entered about other plants that can be used as medicine.

Science Online
bookb.msscience.com/internet_lab

A LOOPY Idea Inspires a "Fastenating" Invention

A wild cocklebur plant inspired the hook-and-loop fastener.

Scientists often spend countless hours in the laboratory dreaming up useful inventions. Sometimes, however, the best ideas hit them in unexpected places at unexpected times. That's why scientists are constantly on the lookout for things that spark their curiosity.

One day in 1948, a Swiss inventor named George deMestral strolled through a field with his dog. When they returned home, deMestral discovered that the dog's fur was covered with cockleburs, parts of a prickly plant. These burs were also stuck to deMestral's jacket and pants. Curious about what made the burs so sticky, the inventor examined one under a microscope.

DeMestral noticed that the cocklebur was covered with lots of tiny hooks. By clinging to animal fur and fabric, this plant is carried to other places. While studying these burs, he got the idea to invent a new kind of fastener that could do the work of buttons, snaps, zippers, and laces—but better!

After years of experimentation, deMestral came up with a strong, durable hook-and-loop fastener made of two strips of nylon fabric. One strip has thousands of small, stiff hooks; the other strip is covered with soft, tiny loops. Today, this hook-and-loop fastening tape is used on shoes and sneakers, watchbands, hospital equipment, space suits, clothing, book bags, and more. You may have one of those hook-and-loop fasteners somewhere on you right now. They're the ones that go rrrrrrrrip when you open them.

So, if you ever get a fresh idea that clings to your mind like a hook to a loop, stick with it and experiment! Who knows? It may lead to a fabulous invention that changes the world!

This photo provides a close-up view of a hook-and-loop fastener.

List Make a list of ten ways hook-and-loop tape is used today. Think of three new uses for it. Since you can buy strips of hook-and-loop fastening tape in most hardware and fabric stores, try out some of your favorite ideas.

Science Online

For more information, visit bookb.msscience.com/oops

(t)Michael Rose/Frank Lane Picture Agency/CORBIS, (b)Dr. Jeremy Burgess/Science Phot[...]rar[...]

Reviewing Main Ideas

Section 1 An Overview of Plants

1. Plants are made up of eukaryotic cells and vary greatly in size and shape.
2. Plants usually have some form of leaves, stems, and roots.
3. As plants evolved from aquatic to land environments, changes occurred in how they reproduced, supported themselves, and moved substances from one part of the plant to another.
4. The plant kingdom is classified into groups called divisions.

Section 2 Seedless Plants

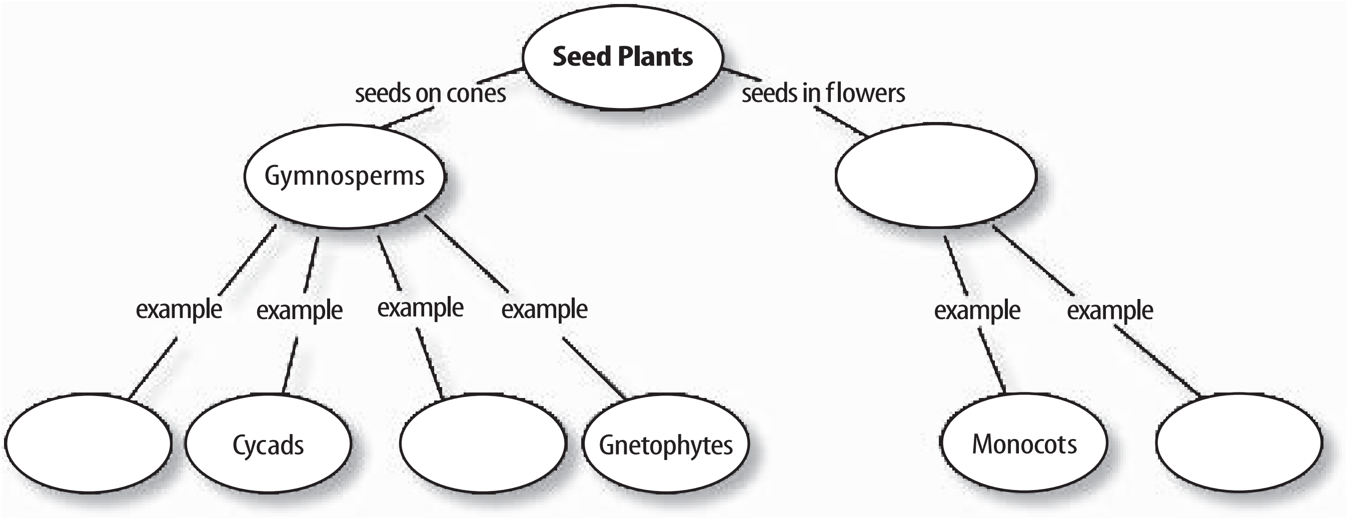
1. Seedless plants include nonvascular and vascular types.
2. Most seedless nonvascular plants have no true leaves, stems, or roots. Reproduction usually is by spores.
3. Seedless vascular plants have vascular tissues that move substances throughout the plant. These plants may reproduce by spores.
4. Many ancient forms of these plants underwent a process that resulted in the formation of coal.

Section 3 Seed Plants

1. Seed plants are adapted to survive in nearly every environment on Earth.
2. Seed plants produce seeds and have vascular tissue, stems, roots, and leaves.
3. The two major groups of seed plants are gymnosperms and angiosperms. Gymnosperms generally have needlelike leaves and some type of cone. Angiosperms are plants that flower and are classified as monocots or dicots.
4. Seed plants are the most economically important plants on Earth.

Visualizing Main Ideas

Copy and complete the following concept map about the seed plants.



chapter 3 Review

Using Vocabulary

angiosperm p. 79
cambium p. 77
cellulose p. 64
cuticle p. 64
dicot p. 80
guard cell p. 75
gymnosperm p. 78
monocot p. 80
nonvascular plant p. 67
phloem p. 77
pioneer species p. 69
rhizoid p. 68
stomata p. 75
vascular plant p. 67
xylem p. 77

Complete each analogy by providing the missing vocabulary word.

1. Angiosperm is to flower as __________ is to cone.
2. Dicot is to two seed leaves as __________ is to one seed leaf.
3. Root is to fern as __________ is to moss.
4. Phloem is to food transport as __________ is to water transport.
5. Vascular plant is to horsetail as __________ is to liverwort.
6. Cellulose is to support as __________ is to protect.
7. Fuel is to ferns as __________ is to bryophytes.
8. Cuticle is to wax as __________ is to fibers.

Checking Concepts

Choose the word or phrase that best answers the question.

9. Which of the following is a seedless vascular plant?
   A) moss **C)** horsetail
   B) liverwort **D)** pine
10. What are the small openings in the surface of a leaf surrounded by guard cells called?
    A) stomata **C)** rhizoids
    B) cuticles **D)** angiosperms
11. What are the plant structures that anchor the plant called?
    A) stems **C)** roots
    B) leaves **D)** guard cells
12. Where is most of a plant's new xylem and phloem produced?
    A) guard cell **C)** stomata
    B) cambium **D)** cuticle
13. What group has plants that are only a few cells thick?
    A) gymnosperms **C)** ferns
    B) cycads **D)** mosses
14. The oval plant parts shown to the right are found only in which plant group?

    A) nonvascular **C)** gymnosperms
    B) seedless **D)** angiosperms
15. What kinds of plants have structures that move water and other substances?
    A) vascular **C)** nonvascular
    B) protist **D)** bacterial
16. In what part of a leaf does most photosynthesis occur?
    A) epidermis **C)** stomata
    B) cuticle **D)** palisade layer
17. Which one of the following do ferns have?
    A) cones **C)** spores
    B) rhizoids **D)** seeds
18. Which of these is an advantage to life on land for plants?
    A) more direct sunlight
    B) less carbon dioxide
    C) greater space to grow
    D) less competition for food

Science Online bookb.msscience.com/vocabulary_puzzlemaker
CONTENTS
Stephen P. Parker/Photo Researchers

Thinking Critically

19. **Predict** what might happen if a land plant's waxy cuticle was destroyed.

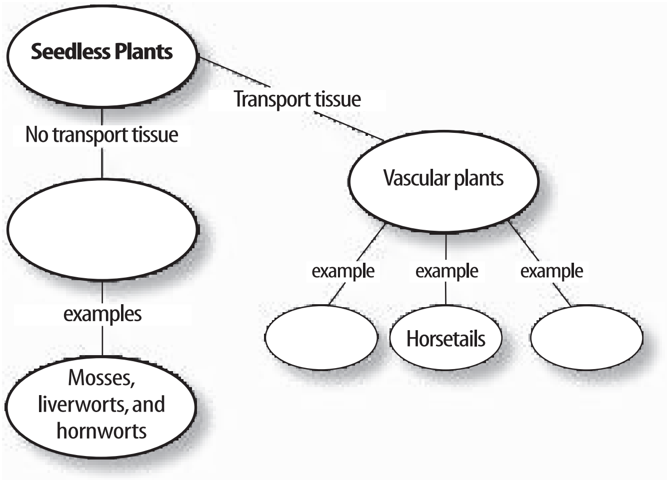
20. **Draw Conclusions** On a walk through the woods with a friend, you find a plant neither of you has seen before. The plant has green leaves and yellow flowers. Your friend says it is a vascular plant. How does your friend know this?

21. **Infer** Plants called succulents store large amounts of water in their leaves, stems, and roots. In what environments would you expect to find succulents growing naturally?

22. **Explain** why mosses usually are found in moist areas.

23. **Recognize Cause and Effect** How do pioneer species change environments so that other plants can grow there?

24. **Concept Map** Copy and complete this map for the seedless plants of the plant kingdom.



25. **Interpret Scientific Illustrations** Using **Figure 20** in this chapter, compare and contrast the number of cotyledons, bundle arrangement in the stem, veins in leaves, and number of flower parts for monocots and dicots.

26. **Sequence** Put the following events in order to show how coal is formed from plants: *living seedless plants, coal is formed, dead seedless plants decay,* and *peat is formed.*

27. **Predict** what would happen if a ring of bark and camium layer were removed from around the trunk of a tree.

Performance Activities

28. **Poem** Choose a topic in this chapter that interests you. Look it up in a reference book, in an encyclopedia, or on a CD-ROM. Write a poem to share what you learn.

29. **Display** Use dried plant material, photos, drawings, or other materials to make a poster describing the form and function of roots, stems, and leaves.

Applying Math

Use the table below to answer questions 30–32.

Number of Stomata (per mm^2)

Plant	Upper Surface	Lower Surface
Pine	50	71
Bean	40	281
Fir	0	228
Tomato	12	13

30. **Gas Exchange** What do the data in this table tell you about where gas exchange occurs in the leaf of each plant species?

31. **Compare Leaf Surfaces** Make two circle graphs—upper surface and lower surface—using the table above.

32. **Guard Cells** On average, how many guard cells are found on the lower surface of a bean leaf?

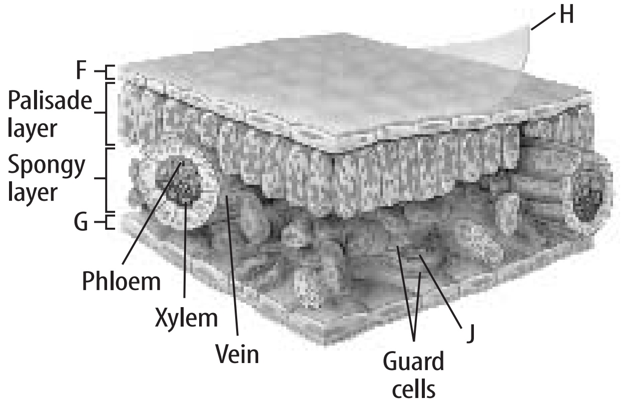
Part 1 Multiple Choice

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

1. Which of the following do plants use to photosynthesize?
   A. blood
   B. iron
   C. chlorophyll
   D. cellulose

2. Which of the following describes the function of the central vacuole in plant cells?
   A. It helps in reproduction.
   B. It helps regulate water content.
   C. It plays a key role in photosynthesis.
   D. It stores food.

Use the illustration below to answer questions 3 and 4.



3. In the leaf cross section, what is indicated by H?
   A. upper epidermis
   B. cuticle
   C. stoma
   D. lower epidermis

4. What flows through the structure indicated by J?
   A. water only
   B. carbon dioxide and water only
   C. oxygen and carbon dioxide only
   D. water, carbon dioxide, and oxygen

5. In seed plants, vascular tissue refers to which of the following?
   A. xylem and phloem only
   B. xylem only
   C. phloem only
   D. xylem, phloem, and cambium

Use the illustration below to answer questions 6 and 7.

6. What is the function of the structure labeled C?
   A. It transports nutrients throughout the plant.
   B. It produces new xylem and phloem.
   C. It transports water from the roots to other parts of the plant.
   D. It absorbs water from outside the plant.

7. What type of vascular tissue is indicated by B?
   A. xylem
   B. cambium
   C. phloem
   D. cellulose

Test-Taking Tip

Eliminate Answer Choices If you don't know the answer to a multiple-choice question, eliminate as many incorrect choices as possible. Mark your best guess from the remaining answers before moving on to the next question.

Part 2 Short Response/Grid In

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

Use the two illustrations below to answer questions 8–10.

8. Identify the flowers shown above as a monocot or a dicot. Explain the differences between the flowers of monocots and dicots.

9. Give three examples of plants represented by Plant A.

10. Give three examples of plants represented by Plant B.

11. How are plants that live on land able to conserve water?

12. Explain why reproductive adaptations were necessary in order for plants to survive on land.

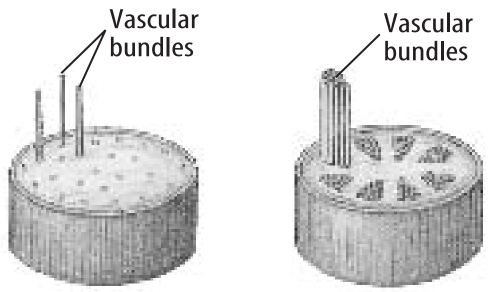
13. You are hiking through a dense forest area and notice some unusual plants growing on the trunk of a tall tree. The plants are no taller than about 3 cm and have delicate stalks. They do not appear to have flowers. Based on this information, what type of plants would you say you found?

14. What is a conifer? To which major group of plants does it belong?

Part 3 Open Ended

Record your answers on a sheet of paper.

Use the two diagrams below to answer questions 15–16.



15. Two plants, A and B, have stem cross sections as shown in the diagrams above. What does the different vascular bundle arrangement tell you about each plant?

16. Draw what the seed from each plant would look like.

17. Create a diagram that describes the life cycle of an annual angiosperm.

18. Discuss the importance of plants in your daily life. Give examples of plants or plant products that you use or consume regularly.

19. Compare and contrast vascular and nonvascular plants. Include examples of each type of plant.

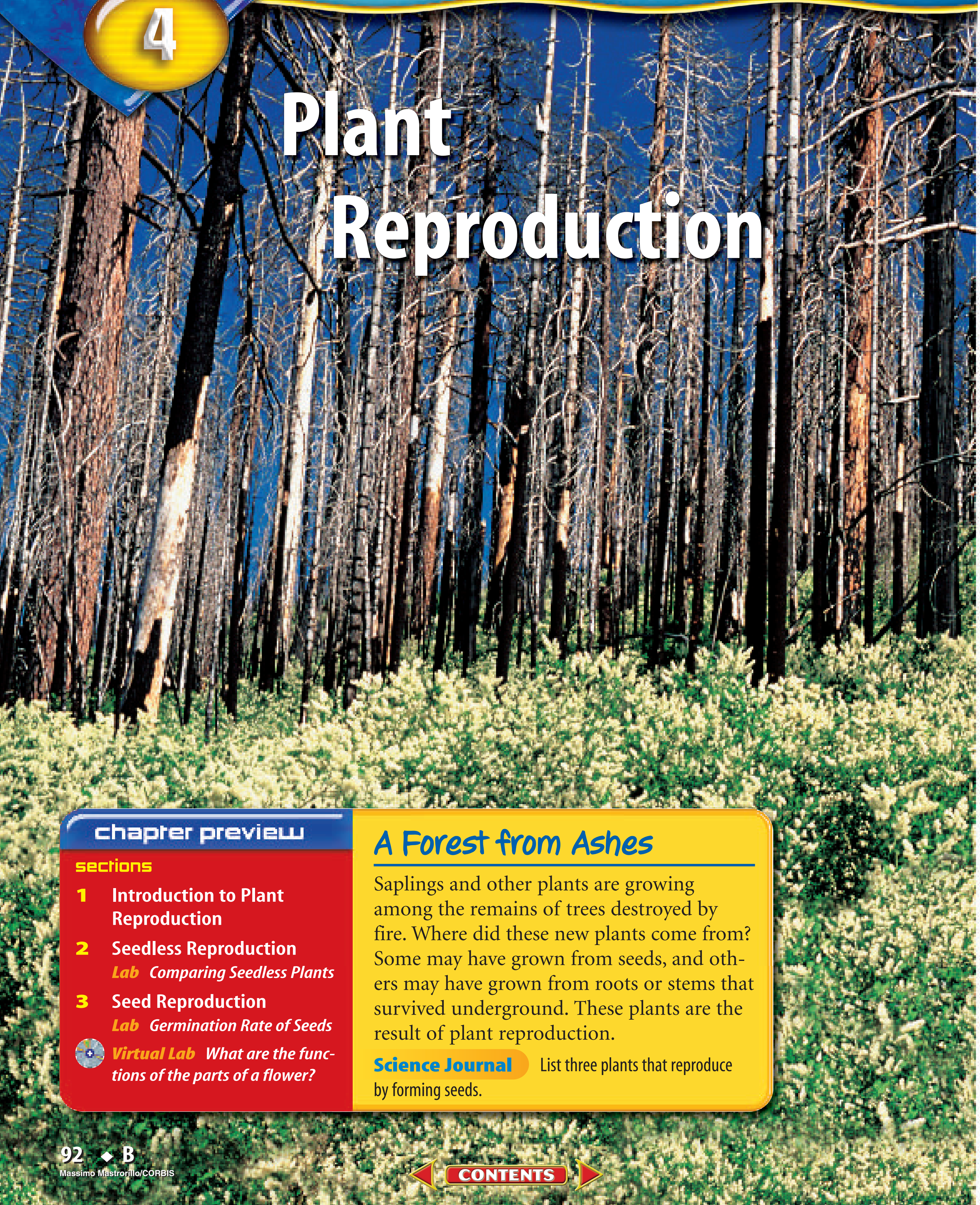
20. Describe the group of plants known as the seedless vascular plants. How do these plants reproduce without seeds?

21. Explain what peat is and how it is formed. How is peat used today?

22. How would our knowledge of ancient plants be different if the fossil record for plants was as plentiful as it is for animals?

chapter 4

Plant Reproduction



chapter preview

sections

1 Introduction to Plant Reproduction

2 Seedless Reproduction

Lab *Comparing Seedless Plants*

3 Seed Reproduction

Lab *Germination Rate of Seeds*

Virtual Lab *What are the functions of the parts of a flower?*

A Forest from Ashes

Saplings and other plants are growing among the remains of trees destroyed by fire. Where did these new plants come from? Some may have grown from seeds, and others may have grown from roots or stems that survived underground. These plants are the result of plant reproduction.

Science Journal List three plants that reproduce by forming seeds.

Massimo Mastrorillo/CORBIS

Start-Up Activities

Launch LAB

Do all fruits contain seeds?

You might know that most plants grow from seeds. Seeds are usually found in the fruits of plants. When you eat watermelon, it can contain many small seeds. Do some plants produce fruits without seeds? Do this lab to find out.

1. Obtain two grapes from your teacher. Each grape should be from a different plant.
2. Split each grape in half and examine the insides of each grape. **WARNING:** *Do not eat the grapes.*
3. **Think Critically** Were seeds found in both grapes? Hypothesize how new grape plants could be grown if no seeds are produced. In your Science Journal, list three other fruits you know of that do not contain seeds.

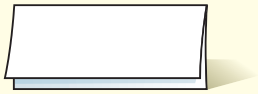
Science Online

Preview this chapter's content and activities at bookb.msscience.com

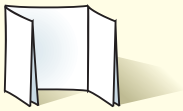
FOLDABLES™ Study Organizer

Plant Reproduction Make the following Foldable to compare and contrast the sexual and asexual characteristics of a plant.

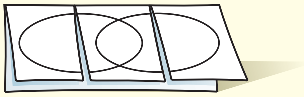
STEP 1 **Fold** one sheet of paper lengthwise.



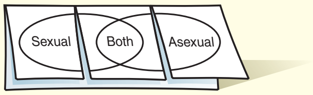
STEP 2 **Fold** into thirds.



STEP 3 **Unfold and draw** overlapping ovals. **Cut** the top sheet along the folds.



STEP 4 **Label** the ovals as shown.



Construct a Venn Diagram As you read the chapter, list the characteristics unique to sexual reproduction under the left tab, those unique to asexual reproduction under the right tab, and those characteristics common to both under the middle tab.

Massimo Mastrorillo/CORBIS

section 1

Introduction to Plant Reproduction

as you read

What You'll Learn

- **Distinguish** between the two types of plant reproduction.
- **Describe** the two stages in a plant's life cycle.

Why It's Important

You can grow new plants without using seeds.

Review Vocabulary

fertilization: in sexual reproduction, the joining of a sperm and an egg

New Vocabulary

- spore
- gametophyte stage
- sporophyte stage

Types of Reproduction

Do people and plants have anything in common? You don't have leaves or roots, and a plant doesn't have a heart or a brain. Despite these differences, you are alike in many ways—you need water, oxygen, energy, and food to grow. Like humans, plants also can reproduce and make similar copies of themselves. Although humans have only one type of reproduction, most plants can reproduce in two different ways, as shown in **Figure 1.**

Sexual reproduction in plants and animals requires the production of sex cells—usually called sperm and eggs—in reproductive organs. The offspring produced by sexual reproduction are genetically different from either parent organism.

A second type of reproduction is called asexual reproduction. This type of reproduction does not require the production of sex cells. During asexual reproduction, one organism produces offspring that are genetically identical to it. Most plants have this type of reproduction, but humans and most other animals don't.

Figure 1 Many plants reproduce sexually with flowers that contain male and female parts. Other plants can reproduce asexually.

In crocus flowers, bees and other insects help get the sperm to the egg.

A cutting from this impatiens plant can be placed in water and will grow new roots. This new plant can then be planted in soil.

(l)Stephen Dalton/Photo Researchers, (r)Matt Meadows

Figure 2 Asexual reproduction in plants takes many forms.

The eyes on these potatoes have begun to sprout. If a potato is cut into pieces, each piece that contains an eye can be planted and will grow into a new potato plant.

Grass plants spread by reproducing asexually.

Asexual Plant Reproduction

Do you like to eat oranges and grapes that have seeds, or do you like seedless fruit? If these plants do not produce seeds, how do growers get new plants? Growers can produce new plants by asexual reproduction because many plant cells have the ability to grow into a variety of cell types. New plants can be grown from just a few cells in the laboratory. Under the right conditions, an entire plant can grow from one leaf or just a portion of the stem or root. When growers use these methods to start new plants, they must make sure that the leaf, stem, or root cuttings have plenty of water and anything else that they need to survive.

Asexual reproduction has been used to produce plants for centuries. The white potatoes shown in **Figure 2** were probably produced asexually. Many plants, such as lawn grasses also shown in **Figure 2,** can spread and cover wide areas because their stems grow underground and produce new grass plants asexually along the length of the stem.

Sexual Plant Reproduction

Although plants and animals have sexual reproduction, there are differences in the way that it occurs. An important event in sexual reproduction is fertilization. Fertilization occurs when a sperm and egg combine to produce the first cell of the new organism, the zygote. How do the sperm and egg get together in plants? In some plants, water or wind help bring the sperm to the egg. For other plants, animals such as insects help bring the egg and sperm together.

Reading Check *How does fertilization occur in plants?*

Mini LAB

Observing Asexual Reproduction

Procedure

1. Using a pair of scissors, cut a stem with at least two pairs of leaves from a coleus or another houseplant.
2. Carefully remove the bottom pair of leaves.
3. Place the cut end of the stem into a cup that is half-filled with water for two weeks. Wash your hands.
4. Remove the new plant from the water and plant it in a small container of soil.

Analysis

1. Draw and label your results in your **Science Journal.**
2. Predict how the new plant and the plant from which it was taken are genetically related.

(l)Holt Studios/Nigel Cattlin/Photo Researchers, (r)Inga Spence/Visuals Unlimited

Figure 3 Some plants can fertilize themselves. Others require two different plants before fertilization can occur.

Flowers of pea plants contain male and female structures, and each flower can fertilize itself.

These holly flowers contain only male reproductive structures, so they can't fertilize themselves.

Compare the flowers of this female holly plant to those of the male plant.

Reproductive Organs A plant's female reproductive organs produce eggs and male reproductive organs produce sperm. Depending on the species, these reproductive organs can be on the same plant or on separate plants, as shown in **Figure 3.** If a plant has both organs, it usually can reproduce by itself. However, some plants that have both sex organs still must exchange sex cells with other plants of the same type to reproduce.

In some plant species, the male and female reproductive organs are on separate plants. For example, holly plants are either female or male. For fertilization to occur, holly plants with flowers that have different sex organs must be near each other. In that case, after the eggs in female holly flowers are fertilized, berries can form.

Another difference between you and a plant is how and when plants produce sperm and eggs. You will begin to understand this difference as you examine the life cycle of a plant.

> **Science Online**
>
> **Topic: Male and Female Plants**
>
> Visit bookb.msscience.com for Web links to information about male and female plants.
>
> **Activity** List four plants that have male and female reproductive structures on separate plants.

Plant Life Cycles

All organisms have life cycles. Your life cycle started when a sperm and an egg came together to produce the zygote that would grow and develop into the person you are today. A plant also has a life cycle. It can start when an egg and a sperm come together, eventually producing a mature plant.

(l)H. Reinhard/OKAPIA/Photo Researchers, (c)John W. Bova/Photo Researchers, (r)John D. Cu[illegible]har

Two Stages During your life cycle, all structures in your body are formed by cell division and are made up of diploid cells—cells with a full set of chromosomes. However, sex cells form by meiosis and are haploid—they have half a set of chromosomes.

Plants have a two-stage life cycle, as shown in **Figure 4.** The two stages are the gametophyte (guh MEE tuh fite) stage and the sporophyte (SPOHR uh fite) stage.

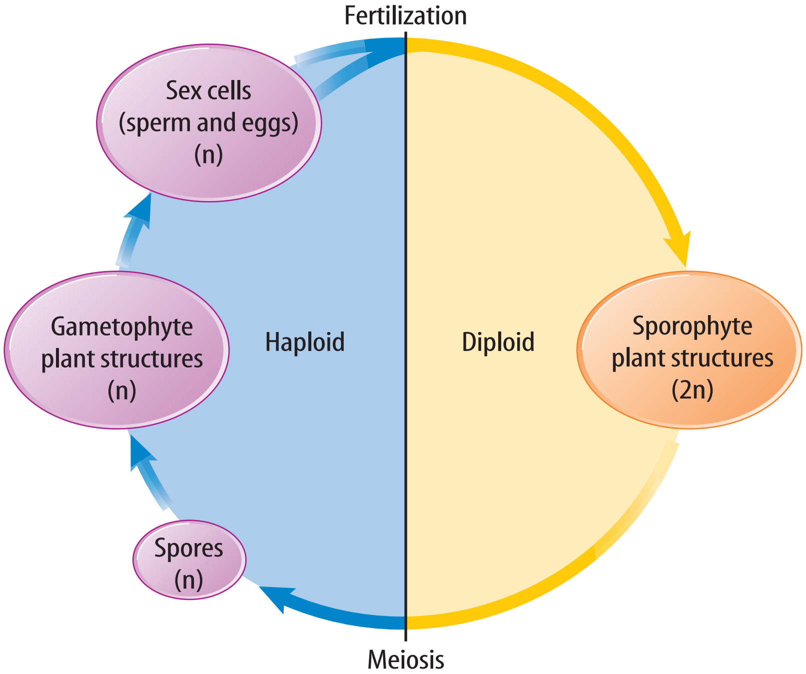


Figure 4 Plants produce diploid and haploid plant structures.
Identify *the process that begins the gametophyte stage.*

Gametophyte Stage When reproductive cells undergo meiosis and produce haploid cells called **spores**, the **gametophyte stage** begins. Spores divide by cell division to form plant structures or an entire new plant. The cells in these structures or plants are haploid. Some of these cells undergo cell division and form sex cells.

Sporophyte Stage Fertilization—the joining of haploid sex cells—begins the **sporophyte stage.** Cells formed in this stage have the diploid number of chromosomes. Meiosis in some of these cells forms spores, and the cycle begins again.

Reading Check *What process begins the sporophyte stage?*

section 1 review

Summary

Types of Reproduction

- Asexual reproduction results in offspring that are genetically identical to the parent plant.
- Sexual reproduction requires fertilization and results in offspring that are genetically different from either parent.
- Female reproductive organs produce eggs.
- Male reproductive organs produce sperm.

Plant Life Cycles

- The gametophyte stage of the plant life cycle begins with meiosis.
- The sporophyte stage begins with fertilization.

Self Check

1. **List** three differences between the gametophyte stage and the sporophyte stage of the plant life cycle.
2. **Describe** how plants reproduce asexually.
3. **Compare and contrast** sexual reproduction in plants and animals.
4. **Think Critically** You admire a friend's houseplant. What would you do to grow an identical plant?

Applying Skills

5. **Draw Conclusions** Using a microscope, you see that the nuclei of a plant's cells contain half the usual number of chromosomes. What is the life cycle stage of this plant?

section 2

Seedless Reproduction

as you read

What You'll Learn

- **Examine** the life cycles of a moss and a fern.
- **Explain** why spores are important to seedless plants.
- **Identify** some special structures used by ferns for reproduction.

Why It's Important

Mosses help build new soil on bare rock or cooled lava, making it possible for other plants to take root.

Review Vocabulary

photosynthesis: food-making process by which plants and many other producers use light energy to produce glucose and oxygen from carbon dioxide and water

New Vocabulary

- frond
- rhizome
- sori
- prothallus

The Importance of Spores

If you want to grow ferns and moss plants, you can't go to a garden store and buy a package of seeds—they don't produce seeds. You could, however, grow them from spores. The sporophyte stage of these plants produces haploid spores in structures called spore cases. When the spore case breaks open, the spores are released and spread by wind or water. The spores, shown in **Figure 5,** can grow into plants that will produce sex cells.

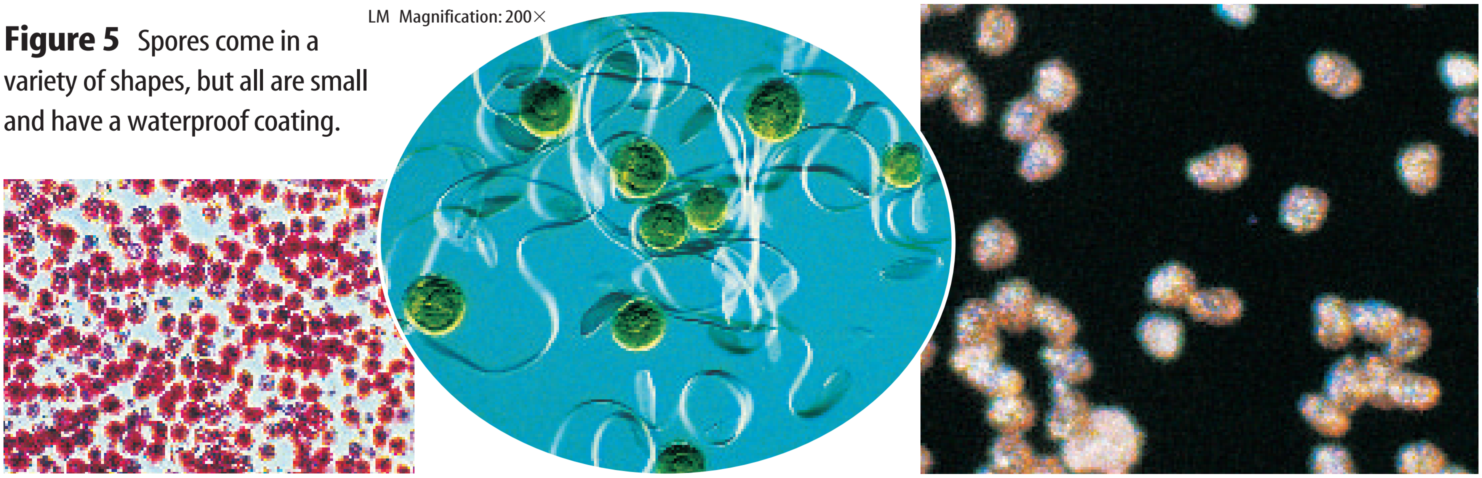
Seedless plants include all nonvascular plants and some vascular plants. Nonvascular plants do not have structures that transport water and substances throughout the plant. Instead, water and substances simply move from cell to cell. Vascular plants have tubelike cells that transport water and substances throughout the plant.

Nonvascular Seedless Plants

If you walked in a damp, shaded forest, you probably would see mosses covering the ground or growing on a log. Mosses, liverworts, and hornworts are all nonvascular plants.

The sporophyte stage of most nonvascular plants is so small that it can be easily overlooked. Moss plants have a life cycle typical of how sexual reproduction occurs in this plant group.

Figure 5 Spores come in a variety of shapes, but all are small and have a waterproof coating.



Moss spores

Horsetail spores

Fern spores

(l)Biology Media/Photo Researchers, (c)Andrew Syred/Science Photo Library/Photo Researche

The Moss Life Cycle You recognize mosses as green, low-growing masses of plants. This is the gametophyte stage, which produces the sex cells. But the next time you see some moss growing, get down and look at it closely. If you see any brownish stalks growing up from the tip of the gametophyte plants, you are looking at the sporophyte stage. The sporophyte stage does not carry on photosynthesis. It depends on the gametophyte for nutrients and water. On the tip of the stalk is a tiny capsule. Inside the capsule millions of spores have been produced. When environmental conditions are just right, the capsule opens and the spores either fall to the ground or are blown away by the wind. New moss gametophytes can grow from each spore and the cycle begins again, as shown in **Figure 6.**

Figure 6 The life cycle of a moss alternates between gametophyte and sporophyte stages.
Identify *the structures that are produced by the gametophyte stage.*

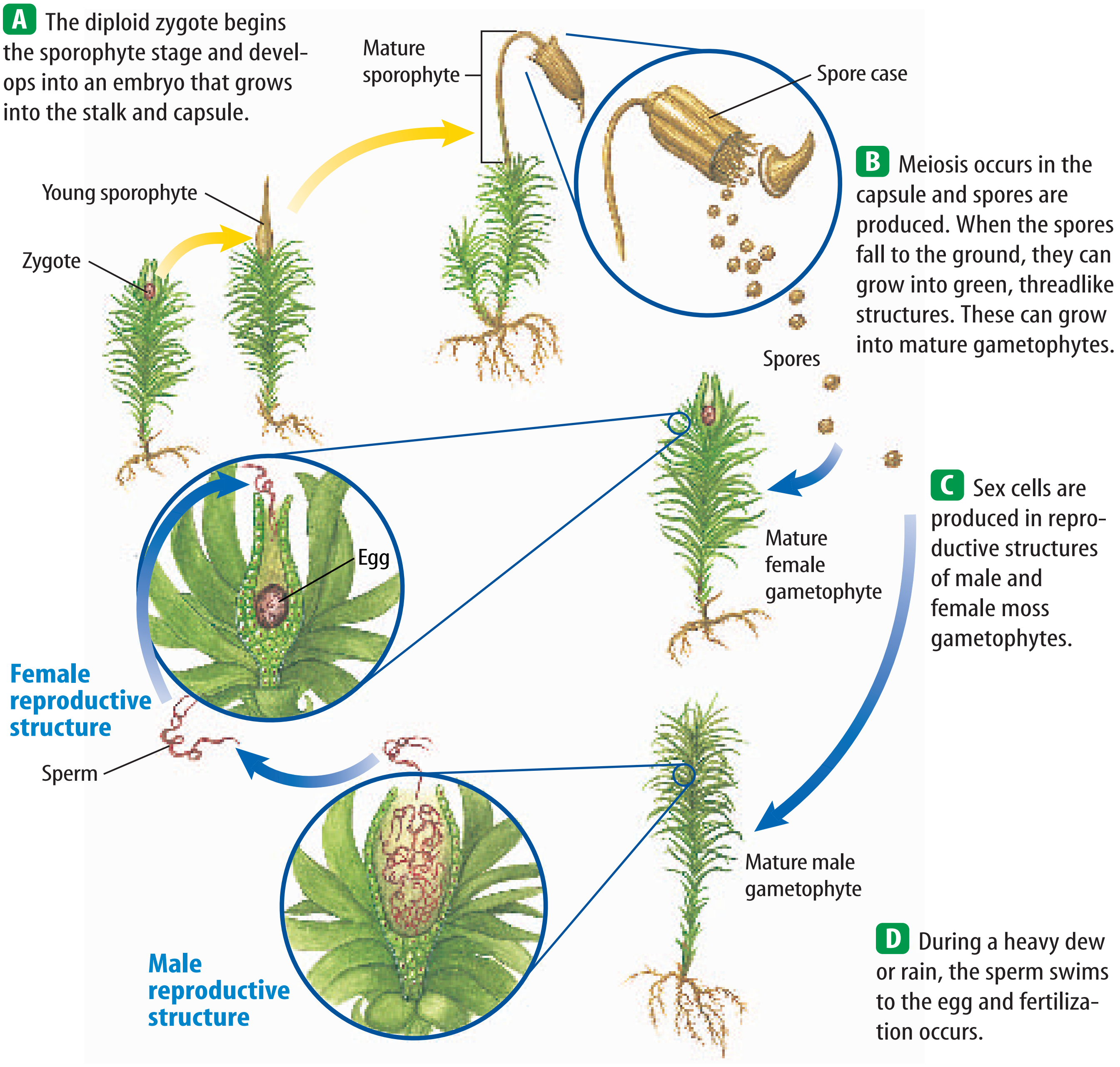


Figure 7 Small balls of cells grow in cuplike structures on the surface of the liverwort.

Nonvascular Plants and Asexual Reproduction Nonvascular plants also can reproduce asexually. For example, if a piece of a moss gametophyte plant breaks off, it can grow into a new plant. Liverworts can form small balls of cells on the surface of the gametophyte plant, as shown in **Figure 7.** These are carried away by water and grow into new gametophyte plants if they settle in a damp environment.

Vascular Seedless Plants

Millions of years ago most plants on Earth were vascular seedless plants. Today they are not as widespread.

Most vascular seedless plants are ferns. Other plants in this group include horsetails and club mosses. All of these plants have vascular tissue to transport water from their roots to the rest of the plant. Unlike the nonvascular plants, the gametophyte of vascular seedless plants is the part that is small and often overlooked.

The Fern Life Cycle The fern plants that you see in nature or as houseplants are fern sporophyte plants. Fern leaves are called **fronds.** They grow from an underground stem called a **rhizome.** Roots that anchor the plant and absorb water and nutrients also grow from the rhizome. Fern sporophytes make their own food by photosynthesis. Fern spores are produced in structures called **sori** (singular, *sorus*), usually located on the underside of the fronds. Sori can look like crusty rust-, brown-, or dark-colored bumps. Sometimes they are mistaken for a disease or for something growing on the fronds.

If a fern spore lands on damp soil or rocks, it can grow into a small, green, heart-shaped gametophyte plant called a **prothallus** (proh THA lus). A prothallus is hard to see because most of them are only about 5 mm to 6 mm in diameter. The prothallus contains chlorophyll and can make its own food. It absorbs water and nutrients from the soil. The life cycle of a fern is shown in **Figure 8.**

Reading Check *What is the gametophyte plant of a fern called?*

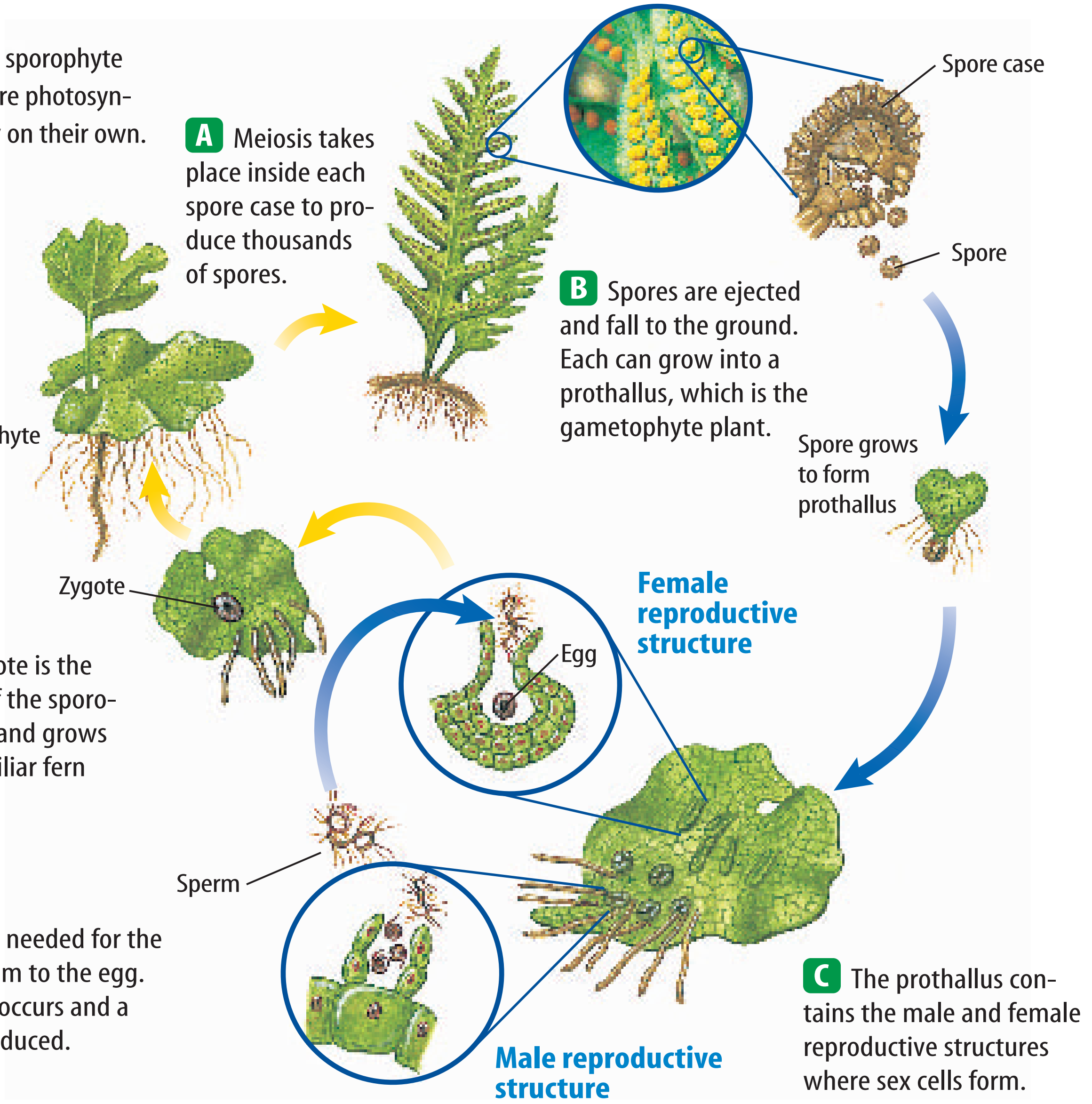
Ferns may reproduce asexually, also. Fern rhizomes grow and form branches. New fronds and roots develop from each branch. The new rhizome branch can be separated from the main plant. It can grow on its own and form more fern plants.

INTEGRATE History

Catapults For thousands of years, humans have used catapults to launch objects. The spore cases of ferns act like tiny catapults as they eject their spores. In your Science Journal list tools, toys, and other objects that have used catapult technology throughout history.

Kathy Merrifield 2000/Photo Researchers

Figure 8 The fern sporophyte and gametophyte are photosynthetic and can grow on their own.



section 2 review

Summary

The Importance of Spores

- Seedless plants reproduce by forming spores.
- Seedless plants include all nonvascular plants and some vascular plants.

Nonvascular Seedless Plants

- Spores are produced by the sporophyte stage and can grow into gametophyte plants.
- The sporophyte cannot photosynthesize.

Vascular Seedless Plants

- Fern sporophytes have green fronds that grow from an underground rhizome.

Self Check

1. **Describe** the life cycle of mosses.
2. **Explain** each stage in the life cycle of a fern.
3. **Compare and contrast** the gametophyte plant of a moss and the gametophyte plant of a fern.
4. **Describe** asexual reproduction in seedless plants.
5. **Think Critically** Why do some seedless plants reproduce only asexually during dry times of the year?

Applying Math

6. **Solve One-Step Equations** If moss spores are 0.1 mm in diameter, how many equal the diameter of a penny?

Kathy Merrifield 2000/Photo Researchers

LAB

Comparing Seedless Plants

All seedless plants have specialized structures that produce spores. Although these sporophyte structures have a similar function, they look different. The gametophyte plants also are different from each other. Do this lab to observe the similarities and differences among three groups of seedless plants.

Real-World Question

How are the gametophyte stages and the sporophyte stages of liverworts, mosses, and ferns similar and different?

Goals

- **Describe** the sporophyte and gametophyte forms of liverworts, mosses, and ferns.
- **Identify** the spore-producing structures of liverworts, mosses, and ferns.

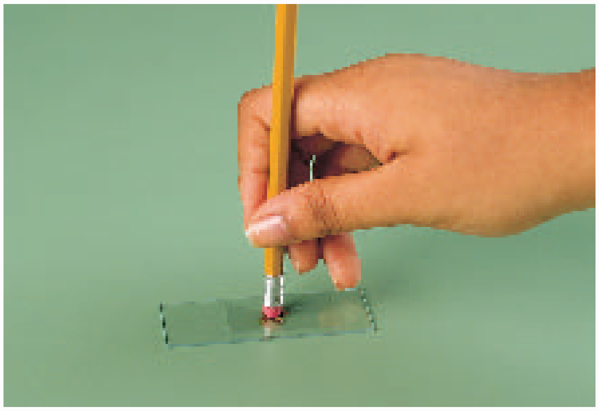
Materials

live mosses, liverworts, and ferns with gametophytes and sporophytes
microscope slides and coverslips (2)
magnifying lens
forceps
dropper
microscope
dissecting needle
pencil with eraser

Safety Precautions

Procedure

1. Obtain a gametophyte of each plant. With a magnifying lens, observe the rhizoids, leafy parts, and stemlike parts, if any are present.
2. Obtain a sporophyte of each plant and use a magnifying lens to observe it.
3. Locate and remove a spore structure of a moss plant. Place it in a drop of water on a slide.



4. Place a coverslip over it. Use the eraser of a pencil to gently push on the coverslip to release the spores. **WARNING:** *Do not break the coverslip.* Observe the spores under low and high power.
5. Make labeled drawings of all observations in your Science Journal.
6. Repeat steps 3 and 4 using a fern.

Conclude and Apply

1. **Compare** the gametophyte's appearance to the sporophyte's appearance for each plant.
2. **List** structure(s) common to all three plants.
3. **Hypothesize** about why each plant produces a large number of spores.

Communicating Your Data

Prepare a bulletin board that shows differences between the sporophyte and gametophyte stages of liverworts, mosses, and ferns. **For more help, refer to the Science Skill Handbook.**

Matt Meadows

section 3

Seed Reproduction

(l)John Kaprielian/Photo Researchers, (r)Scott Camazine/Sue Trainor/Photo Researchers

The Importance of Pollen and Seeds

All the plants described so far have been seedless plants. However, the fruits and vegetables that you eat come from seed plants. Oak, maple, and other shade trees are also seed plants. All flowers are produced by seed plants. In fact, most of the plants on Earth are seed plants. How do you think they became such a successful group? Reproduction that involves pollen and seeds is part of the answer.

Pollen In seed plants, some spores develop into small structures called pollen grains. A **pollen grain**, as shown in **Figure 9**, has a water-resistant covering and contains gametophyte parts that can produce the sperm. The sperm of seed plants do not need to swim to the female part of the plant. Instead, they are carried as part of the pollen grain by gravity, wind, water currents, or animals. The transfer of pollen grains to the female part of the plant is called **pollination**.

After the pollen grain reaches the female part of a plant, sperm and a pollen tube are produced. The sperm moves through the pollen tube, then fertilization can occur.

as you read

What You'll Learn

- **Examine** the life cycles of typical gymnosperms and angiosperms.
- **Describe** the structure and function of the flower.
- **Discuss** methods of seed dispersal in seed plants.

Why It's Important

Seeds from cones and flowers produce most plants on Earth.

Review Vocabulary

gymnosperms: vascular plants that do not flower, generally have needlelike or scalelike leaves, and produce seeds that are not protected by fruit

New Vocabulary

- pollen grain
- pollination
- ovule
- stamen
- pistil
- ovary
- germination

Figure 9 The waterproof covering of a pollen grain is unique and can be used to identify the plant that it came from. This pollen from a ragweed plant is a common cause of hay fever.

Color-enhanced SEM Magnification: 3000×

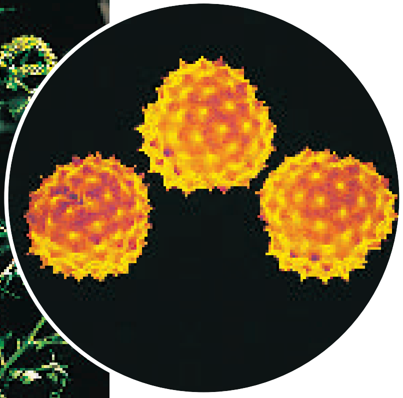
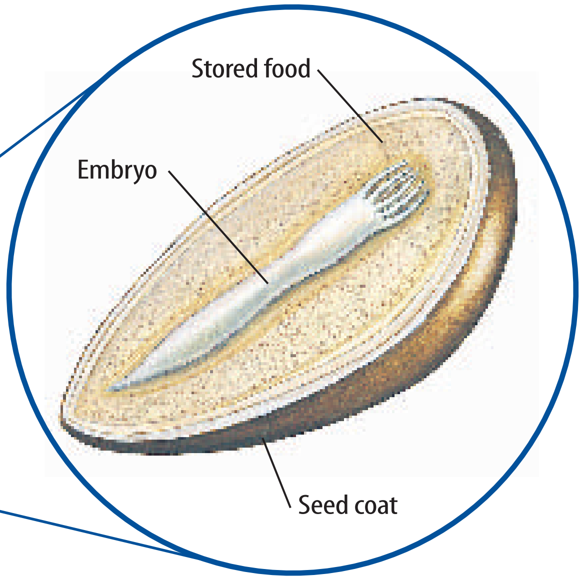


Figure 10 Seeds have three main parts—a seed coat, stored food, and an embryo. This pine seed also has a wing.
Infer *the function of the wing.*



Seeds Following fertilization, the female part can develop into a seed. A seed consists of an embryo, stored food, and a protective seed coat, as shown in **Figure 10.** The embryo has structures that eventually will produce the plant's stem, leaves, and roots. In the seed, the embryo grows to a certain stage and then stops until the seed is planted. The stored food provides energy that is needed when the plant embryo begins to grow into a plant. Because the seed contains an embryo and stored food, a new plant can develop more rapidly from a seed than from a spore.

Reading Check *What are the three parts of a seed?*

Gymnosperms (JIHM nuh spurmz) and angiosperms are seed plants. One difference between the two groups is the way seeds develop. In gymnosperms, seeds usually develop in cones—in angiosperms, seeds develop in flowers and fruit.

ScienceOnline

Topic: Seed Banks
Visit bookb.msscience.com for Web links to information about conserving the seeds of many useful and endangered plants.

Activity List three organizations that manage seed banks, and give examples of the kinds of plants each organization works to conserve.

Gymnosperm Reproduction

If you have collected pine cones or used them in a craft project, you probably noticed that many shapes and sizes of cones exist. You probably also noticed that some cones contain seeds. Cones are the reproductive structures of gymnosperms. Each gymnosperm species has a different cone.

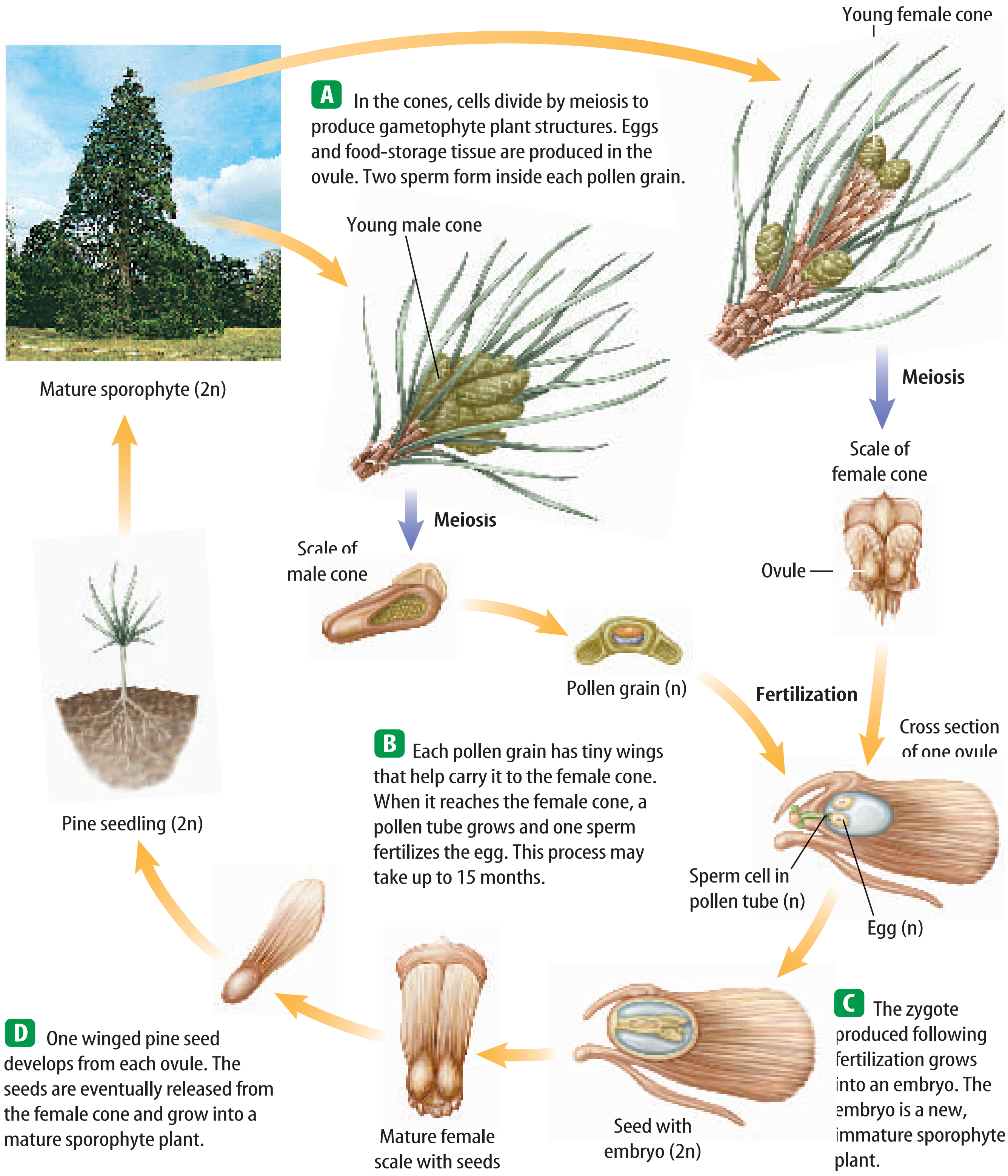
Gymnosperm plants include pines, firs, cedars, cycads, and ginkgoes. The pine is a familiar gymnosperm. Production of seeds in pines is typical of most gymnosperms.

Cones A pine tree is a sporophyte plant that produces male cones and female cones as shown in **Figure 11.** Male and female gametophyte structures are produced in the cones but you'd need a magnifying lens to see these structures clearly.

Dr. WM. H. Harlow/Photo Researchers

A mature female cone consists of a spiral of woody scales on a short stem. At the base of each scale are two ovules. The egg is produced in the **ovule.** Pollen grains are produced in the smaller male cones. In the spring, clouds of pollen are released from the male cones. Anything near pine trees might be covered with the yellow, dustlike pollen.

Figure 11 Seed formation in pines, as in most gymnosperms, involves male and female cones.



Christian Grzimek/OKAPIA/Photo Researchers

Figure 12 Seed development can take more than one year in pines. The female cone looks different at various stages of the seed-production process.

Cone at pollination | Cone at the end of the first year | Mature, second-year cone

INTEGRATE Environment

Seed Germination Some gymnosperm seeds will not germinate until the heat of a fire causes the cones to open and release the seeds. Without fires, these plants cannot reproduce. In your Science Journal, explain why some forest fires could be good for the environment.

Gymnosperm Seeds Pollen is carried from male cones to female cones by the wind. However, most of the pollen falls on other plants, the ground, and bodies of water. To be useful, the pollen has to be blown between the scales of a female cone. There it can be trapped in the sticky fluid secreted by the ovule. If the pollen grain and the female cone are the same species, fertilization and the formation of a seed can take place.

If you are near a pine tree when the female cones release their seeds, you might hear a crackling noise as the cones' scales open. It can take a long time for seeds to be released from a female pine cone. From the moment a pollen grain falls on the female cone until the seeds are released, can take two or three years, as shown in **Figure 12.** In the right environment, each seed can grow into a new pine sporophyte.

Angiosperm Reproduction

You might not know it, but you are already familiar with angiosperms. If you had cereal for breakfast or bread in a sandwich for lunch, you ate parts of angiosperms. Flowers that you send or receive for special occasions are from angiosperms. Most of the seed plants on Earth today are angiosperms.

All angiosperms have flowers. The sporophyte plant produces the flowers. Flowers are important because they are reproductive organs. Flowers contain gametophyte structures that produce sperm or eggs for sexual reproduction.

(l)Stephen P. Parker/Photo Researchers, (c)M. J. Griffith/Photo Researchers, (r)Dan Suzio/Phot ear

The Flower When you think of a flower, you probably imagine something with a pleasant aroma and colorful petals. Although many such flowers do exist, some flowers are drab and have no aroma, like the flowers of the maple tree shown in **Figure 13.** Why do you think such variety among flowers exists?

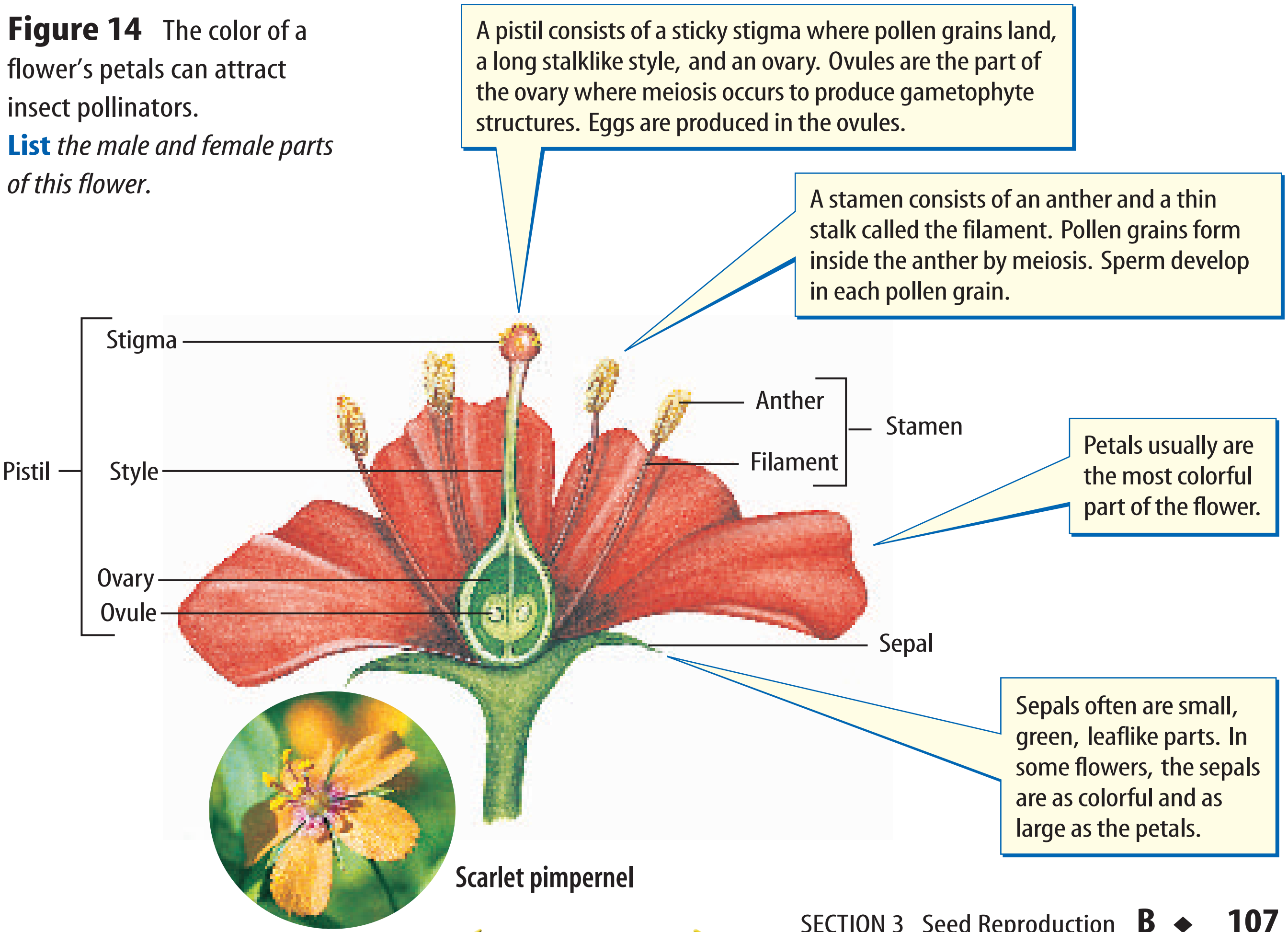
Most flowers have four main parts—petals, sepals, stamen, and pistil—as shown in **Figure 14.** Generally, the colorful parts of a flower are the petals. Outside the petals are usually leaflike parts called sepals. Sepals form the outside of the flower bud. Sometimes petals and sepals are the same color.

Inside the flower are the reproductive organs of the plant. The **stamen** is the male reproductive organ. Pollen is produced in the stamen. The **pistil** is the female reproductive organ. The **ovary** is the swollen base of the pistil where ovules are found. Not all flowers have every one of the four parts. Remember the holly plants you learned about at the beginning of the chapter? What flower part would be missing on a flower from a male holly plant?

Reading Check *Where are ovules found in the flower?*

Figure 13 Maple trees produce clusters of flowers early in the spring.
Describe *how these flowers are different from those of the crocus shown in Figure 1.*

Figure 14 The color of a flower's petals can attract insect pollinators.
List *the male and female parts of this flower.*



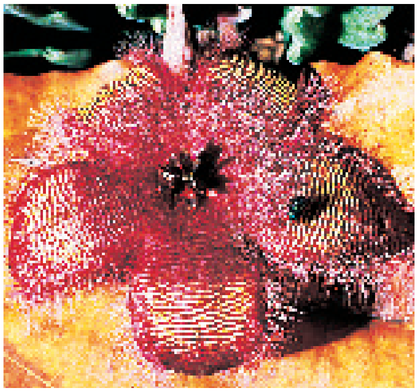
ber/Visuals Unlimited, (tr)Rob Simpson/Visuals Unlimited, (b)Alvin E. Staffan/Photo Researchers

Figure 15 Looking at flowers will give you a clue about how each one is pollinated.

Honeybees are important pollinators. They are attracted to brightly colored flowers, especially blue and yellow flowers.

Flowers that are pollinated at night, like this cactus flower being pollinated by a bat, are usually white.

Flowers that are pollinated by hummingbirds usually are brightly colored, especially bright red and yellow.



Flowers that are pollinated by flies usually are dull red or brown. They often have a strong odor like rotten meat.

The flower of this wheat plant does not have a strong odor and is not brightly colored. Wind, not an animal, is the pollinator of wheat and most other grasses.

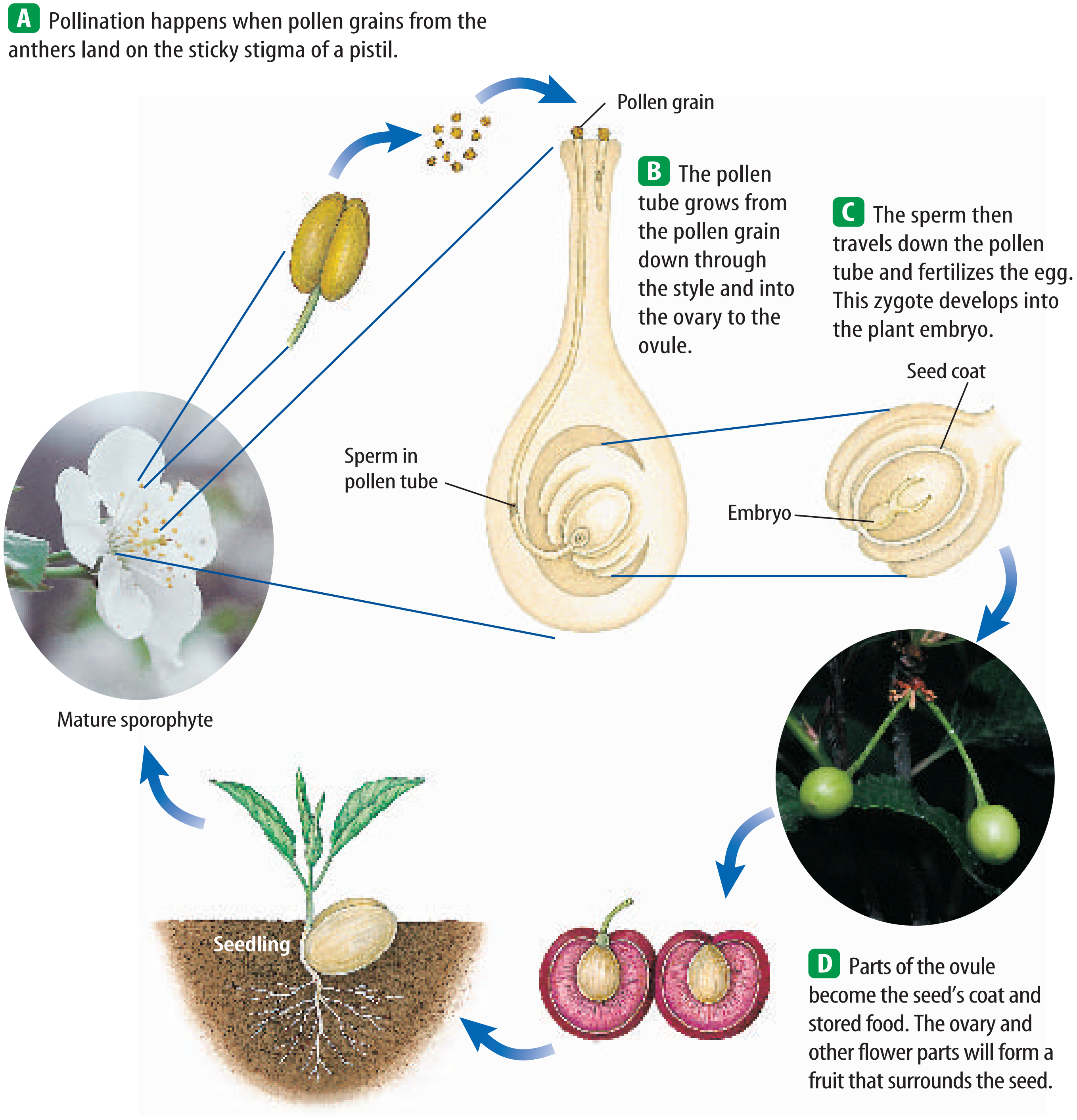
(tl)C. Nuridsany & M. Perennou/Science Photo Library/Photo Researchers, (tr)Merlin D. Tuttle/Photo Researchers, (bl)Anthony Mercreca Photo/Photo Researchers, (bc)Kjell B. Sandved/Photo Researchers, (br)Holt Studios LTD/Photo Researchers

Importance of Flowers The appearance of a plant's flowers can tell you something about the life of the plant. Large flowers with brightly colored petals often attract insects and other animals, as shown in **Figure 15.** These animals might eat the flower, its nectar, or pollen. As they move about the flower, the animals get pollen on their wings, legs, or other body parts. Later, these animals spread the flower's pollen to other plants that they visit. Other flowers depend on wind, rain, or gravity to spread their pollen. Their petals can be small or absent. Flowers that open only at night, such as the cactus flower in **Figure 15,** usually are white or yellow and have strong scents to attract animal pollinators. Following pollination and fertilization, the ovules of flowers can develop into seeds.

Reading Check *How do animals spread pollen?*

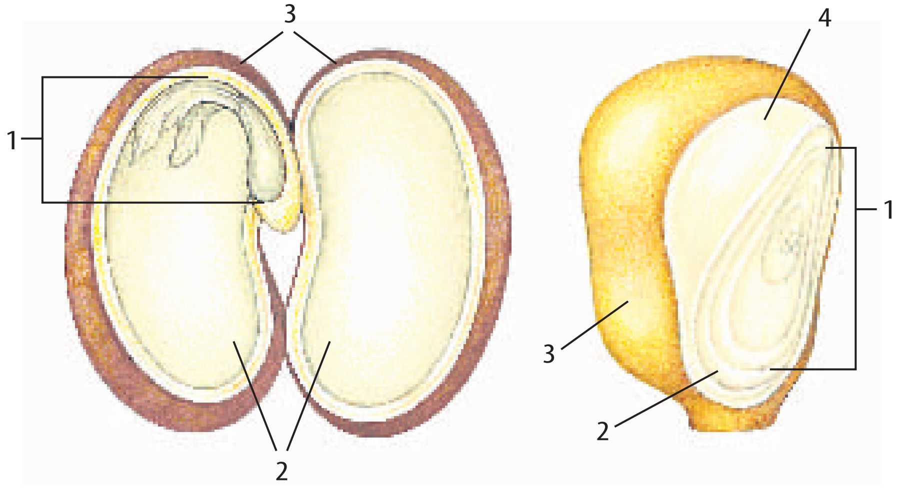
Angiosperm Seeds The development of angiosperm seeds is shown in **Figure 16.** Pollen grains reach the stigma in a variety of ways. Pollen is carried by wind, rain, or animals such as insects, birds, and mammals. A flower is pollinated when pollen grains land on the sticky stigma. A pollen tube grows from the pollen grain down through the style. The pollen tube enters the ovary and reaches an ovule. The sperm then travels down the pollen tube and fertilizes the egg in the ovule. A zygote forms and grows into the plant embryo.

Figure 16 In angiosperms, seed formation begins with the formation of sperm and eggs in the male and female flower parts.



William J. Weber/Visuals Unlimited

Figure 17 Seeds of land plants are capable of surviving unfavorable environmental conditions.
1. Immature plant
2. Cotyledon(s)
3. Seed coat
4. Endosperm



Seed Development Parts of the ovule develop into the stored food and the seed coat that surround the embryo, and a seed is formed, as shown in **Figure 17.** In the seeds of some plants, like beans and peanuts, the food is stored in structures called cotyledons. The seeds of other plants, like corn and wheat, have food stored in a tissue called endosperm.

Seed Dispersal

INTEGRATE Earth Science Sometimes, plants just seem to appear. They probably grew from a seed, but where did the seed come from? Plants have many ways of dispersing their seeds, as shown in **Figure 18.** Most seeds grow only when they are placed on or in soil. Do you know how seeds naturally get to the soil? For many seeds, gravity is the answer. They fall onto the soil from the parent plant on which they grew. However, in nature some seeds can be spread great distances from the parent plant.

Wind dispersal usually occurs because a seed has an attached structure that moves it with air currents. Some plants have very small seeds that become airborne when released by the plant.

Reading Check *How can wind disperse seeds?*

Animals can disperse many seeds. Some seeds are eaten with fruits, pass through an animal's digestive system, and are dispersed as the animal moves from place to place. Seeds can be carried great distances and stored or buried by animals. Attaching to fur, feathers, and clothing is another way that seeds are dispersed by animals.

Water also disperses seeds. Raindrops can knock seeds out of a dry fruit. Some fruits and seeds float on flowing water or ocean currents. When you touch the seedpod of an impatiens flower, it explodes. The tiny seeds are ejected and spread some distance from the plant.

Mini LAB

Modeling Seed Dispersal

Procedure
1. Find a **button** you can use to represent a seed.
2. Examine the seeds pictured in **Figure 18** and invent a way that your button seed could be dispersed by wind, water, on the fur of an animal, or by humans.
3. Bring your button seed to class and demonstrate how it could be dispersed.

Analysis
1. Explain how your button seed was dispersed.
2. In your **Science Journal,** write a paragraph describing your model. Also describe other ways you could model seed dispersal.

Try at Home

NATIONAL GEOGRAPHIC

VISUALIZING SEED DISPERSAL

Figure 18

Plants have many adaptations for dispersing seeds, often enlisting the aid of wind, water, or animals.

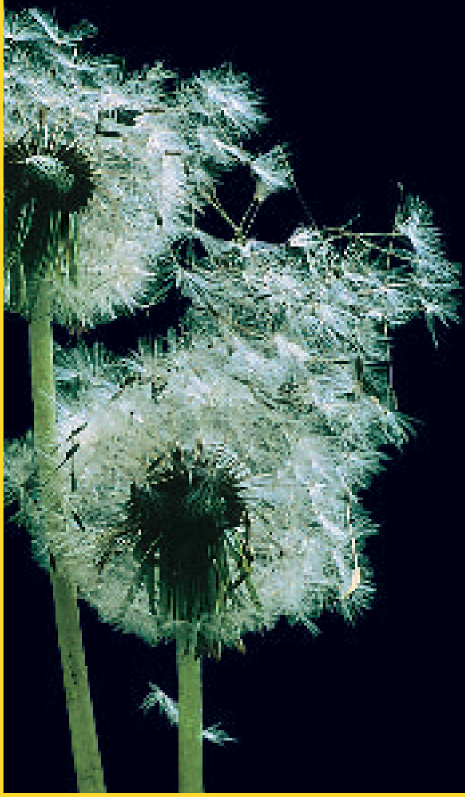
▲ Equipped with tiny hooks, burrs cling tightly to fur and feathers.

▲ Pressure builds within the seed-pods of this jewelweed plant until the pod bursts, flinging seeds far and wide.

▼ Some seeds buried by animals, such as this squirrel, go uneaten and sprout the next spring.

▲ Encased in a thick, buoyant husk, a coconut may be carried hundreds of kilometers by ocean currents.

▼ Dandelion seeds are easily dislodged and sail away on a puff of wind.



▶ Blackberry seeds eaten by this white-footed mouse will pass through its digestive tract and be deposited in a new location.

CONTENTS

n S /CORBIS, (bcl)Tom & Pat Leeson, (bcr)Darryl Torckler/Stone/Getty Images, (others)Dwight Kuhn

Germination A series of events that results in the growth of a plant from a seed is called **germination.** When dispersed from the plant, some seeds germinate in just a few days and other seeds take weeks or months to grow. Some seeds can stay in a resting stage for hundreds of years. In 1982, seeds of the East Indian lotus sprouted after 466 years.

Seeds will not germinate until environmental conditions are right. Temperature, the presence or absence of light, availability of water, and amount of oxygen present can affect germination. Sometimes the seed must pass through an animal's digestive system before it will germinate. Germination begins when seed tissues absorb water. This causes the seed to swell and the seed coat to break open.

Applying Math — Calculate Using Percents

HOW MANY SEEDS WILL GERMINATE? The label on a packet of carrot seeds says that it contains about 200 seeds. It also claims that 95 percent of the seeds will germinate. How many seeds should germinate if the packet is correct?

Solution

1 *This is what you know:*
- quantity = 200
- percentage = 95

2 *This is what you need to find out:*
What is 95 percent of 200?

3 *This is the procedure you need to use:*
- Set up the equation for finding percentage: $\frac{95}{100} = \frac{x}{200}$
- Solve the equation for x: $x = \frac{95 \times 200}{100}$

4 *Check your answer:*
Divide by 200 then multiply by 100. You should get the original percentage of 95.

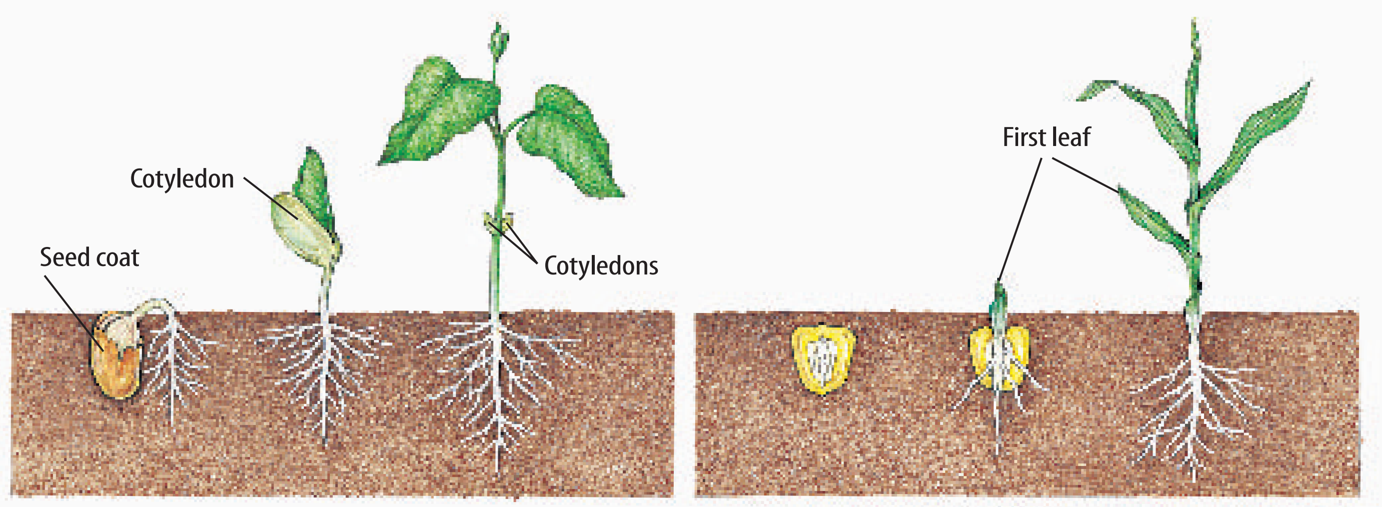
Practice Problems

1. The label on a packet of 50 corn kernels claims that 98 percent will germinate. How many kernels will germinate if the packet is correct?
2. A seed catalog states that a packet contains 1,120 spinach seeds with a germination rate of 65 percent. How many spinach plants should the packet produce?

Science Online
For more practice, visit bookb.msscience.com/math_practice

Doug Martin

Figure 19 Seed germination results in a new plant.



In beans, the cotyledons rise above the soil. As the stored food is used, the cotyledons shrivel and fall off.

In corn, the stored food in the endosperm remains in the soil and is gradually used as the plant grows.

Next, a series of chemical reactions occurs that releases energy from the stored food in the cotyledons or endosperm for growth. Eventually, a root grows from the seed, followed by a stem and leaves as shown in **Figure 19.** After the plant emerges from the soil, photosynthesis can begin. Photosynthesis provides food as the plant continues to grow.

section 3 review

Summary

The Importance of Pollen and Seeds

- In seed plants, spores develop into pollen grains.
- Pollination is the transfer of pollen from a male plant part to a female plant part.

Gymnosperm Reproduction

- Cones are reproductive structures of gymnosperms.
- Seeds are produced in female cones.

Angiosperm Reproduction

- Flowers are reproductive structures of angiosperms.
- Female flower parts develop into seeds.

Seed Dispersal

- Seeds can be dispersed in several ways.
- Germination is the growth of a plant from a seed.

Self Check

1. **Compare and contrast** the life cycles of gymnosperms and angiosperms.
2. **Draw and label** a diagram showing all four parts of a flower.
3. **Describe** the three parts of a seed and their functions.
4. **Explain** the process of germination.
5. **Think Critically** Walnut trees produce edible seeds with a hard outer covering. Maple trees produce seeds with winglike edges. What type of seed dispersal applies to each type of tree?

Applying Skills

6. **Research information** to find out what conditions are needed for seed germination of three plants, such as corn, peas, and beans. How long does each type of seed take to germinate?

LAB Design Your Own

Germination Rate of Seeds

Goals

- **Design** an experiment to test the effect of an environmental factor on seed germination rate.
- **Compare** germination rates under different conditions.

Possible Materials

seeds
water
salt
potting soil
plant trays or plastic cups
**seedling warming cables*
thermometer
graduated cylinder
beakers

**Alternate materials*

Safety Precautions

WARNING: *Some kinds of seeds are poisonous. Do not place any seeds in your mouth. Be careful when using any electrical equipment to avoid shock hazards.*

Real-World Question

Many environmental factors affect the germination rate of seeds. Among these are soil temperature, air temperature, moisture content of soil, and salt content of soil. What happens to the germination rate when one of these variables is changed? How do environmental factors affect seed germination? Can you determine a way to predict the best conditions for seed germination?

Form a Hypothesis

Based on your knowledge of seed germination, state a hypothesis to explain how environmental factors affect germination rates.

Doug Martin

Using Scientific Methods

Matt Meadows

Test Your Hypothesis

Make a Plan

1. As a group, agree upon and write your hypothesis and decide how you will test it. Identify which results will confirm the hypothesis.
2. **List** the steps you need to take to test your hypothesis. Be specific, and describe exactly what you will do at each step. List your materials.
3. **Prepare** a data table in your Science Journal to record your observations.
4. Reread your entire experiment to make sure that all of the steps are in a logical order.
5. **Identify** all constants, variables, and controls of the experiment.

Follow Your Plan

1. Make sure your teacher approves your plan and your data table before you proceed.
2. Use the same type and amount of soil in each tray.
3. While the experiment is going on, record your observations accurately and complete the data table in your Science Journal.

Analyze Your Data

1. **Compare** the germination rate in the two groups of seeds.
2. **Compare** your results with those of other groups.
3. Did changing the variable affect germination rates? Explain.
4. Make a bar graph of your experimental results.

Conclude and Apply

1. **Interpret** your graph to estimate the conditions that give the best germination rate.
2. **Describe** the conditions that affect germination rate.

Communicating Your Data

Write a short article for a local newspaper telling about this experiment. Give some ideas about when and how to plant seeds in the garden and the conditions needed for germination.

Genetic Engineering

Genetically modified "super" corn can resist heat, cold, drought, and insects.

What would happen if you crossed a cactus with a rose? Well, you'd either get an extra spiky flower, or a bush that didn't need to be watered very often. Until recently, this sort of mix was the stuff science fiction was made of. But now, with the help of genetic engineering, it may be possible.

Genetic engineering is a way of taking genes—sections of DNA that produce certain traits, like the color of a flower or the shape of a nose—from one species and giving them to another.

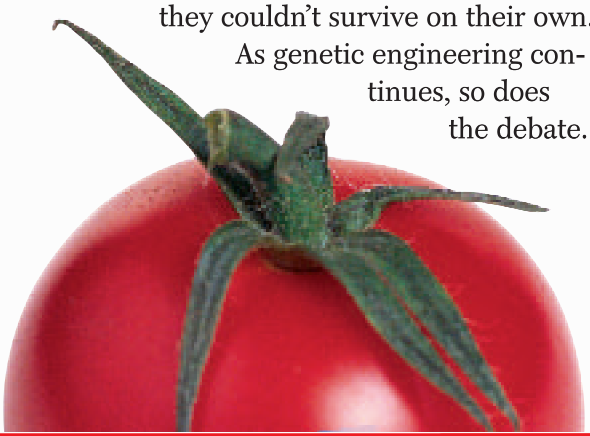
In 1983, the first plant was genetically modified, or changed. Since then, many crops in the U.S. have been modified in this way, including soybeans, potatoes, tomatoes, and corn.

One purpose of genetic engineering is to transfer an organism's traits. For example, scientists have changed lawn grass by adding to it the gene from another grass species. This gene makes lawn grass grow slowly, so it doesn't have to be mowed very often. Genetic engineering can also make plants that grow bigger and faster, repel insects, or resist herbicides. These changes could allow farmers to produce more crops with fewer chemicals. Scientists predict that genetic engineering soon will produce crops that are more nutritious and that can resist cold, heat, or even drought.

Genetic engineering is a relatively new process, and some people are worried about the long-term risks. One concern is that people might be allergic to modified foods and not realize it until it's too late. Other people say that genetic engineering is unnatural. Also, farmers must purchase the patented genetically modified seeds each growing season from the companies that make them, rather than saving and replanting the seeds from their current crops.

People in favor of genetic engineering reply that there are always risks with new technology, but proper precautions are being taken. Each new plant is tested and then approved by U.S. governmental agencies. And they say that most "natural" crops aren't really natural. They are really hybrid plants bred by agriculturists, and they couldn't survive on their own.

As genetic engineering continues, so does the debate.



Debate Research the pros and cons of genetic engineering at the link shown to the right. Decide whether you are for or against genetic engineering. Debate your decision with a classmate.

Science Online
For more information, visit bookb.msscience.com/time

(t)Kevin Laubacher/FPG, (b)Michael Black/Bruce Coleman, Inc.

Reviewing Main Ideas

Section 1 Introduction to Plant Reproduction

1. Plants reproduce sexually and asexually. Sexual reproduction involves the formation of sex cells and fertilization.
2. Asexual reproduction does not involve sex cells and produces plants genetically identical to the parent plant.
3. Plant life cycles include a gametophyte and a sporophyte stage. The gametophyte stage begins with meiosis. The sporophyte stage begins when the egg is fertilized by a sperm.
4. In some plant life cycles, the sporophyte and gametophyte stages are separate and not dependent on each other. In other plant life cycles, they are part of the same organism.

Section 2 Seedless Reproduction

1. For liverworts and mosses, the gametophyte stage is the familiar plant form. The sporophyte stage produces spores.
2. In ferns, the sporophyte stage is the familiar plant form.
3. Seedless plants, like mosses and ferns, use sexual reproduction to produce spores.

Section 3 Seed Reproduction

1. In seed plants the male reproductive organs produce pollen grains that eventually contain sperm. Eggs are produced in the ovules of the female reproductive organs.
2. The male and female reproductive organs of gymnosperms are called cones. Wind usually moves pollen from the male cone to the female cone for pollination.
3. The reproductive organs of angiosperms are in a flower. The male reproductive organ is the stamen, and the female reproductive organ is the pistil. Gravity, wind, rain, and animals can pollinate a flower.
4. Seeds of gymnosperms and angiosperms are dispersed in many ways. Wind, water, and animals spread seeds. Some plants can eject their seeds.
5. Germination is the growth of a plant from a seed.

Visualizing Main Ideas

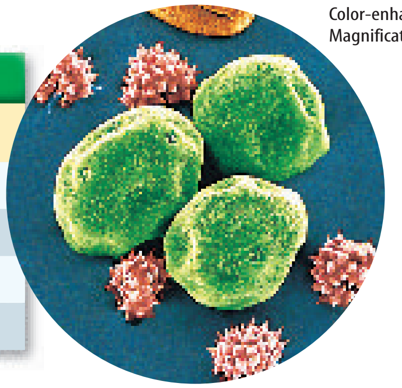
Copy and complete the following table that compares reproduction in different plant groups.

Plant Reproduction

Plant Group	Seeds?	Pollen?	Cones?	Flowers?
Mosses				
Ferns				
Gymnosperms				
Angiosperms				

Do not write in this book.

Color-enhanced SEM Magnification: 100×



Oliver Meckes/Photo Researchers

Using Vocabulary

frond p. 100	pollination p. 103
gametophyte stage p. 97	prothallus p. 100
germination p. 112	rhizome p. 100
ovary p. 107	sori p. 100
ovule p. 105	spore p. 97
pistil p. 107	sporophyte stage p. 97
pollen grain p. 103	stamen p. 107

Fill in the blank with the correct vocabulary word or words.

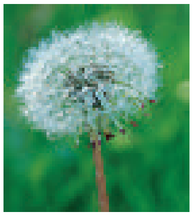
1. A(n) ________ is the leaf of a fern.
2. In seed plants, the ________ contains the egg.
3. The plant structures in the ________ are made up of haploid cells.
4. The green, leafy moss plant is part of the ________ in the moss life cycle.
5. Two parts of a sporophyte fern are a frond and ________.
6. The female reproductive organ of the flower is the ________.
7. The ________ is the swollen base of the pistil.

Checking Concepts

Choose the word or phrase that best answers the question.

8. How are colorful flowers usually pollinated?
   A) insects **C)** clothing
   B) wind **D)** gravity
9. What type of reproduction produces plants that are genetically identical?
   A) asexual **C)** spore
   B) sexual **D)** flower
10. Which of the following terms describes the cells in the gametophyte stage?
   A) haploid **C)** diploid
   B) prokaryote **D)** missing a nucleus
11. What structures do ferns form when they reproduce sexually?
   A) spores **C)** seeds
   B) anthers **D)** flowers
12. What contains food for the plant embryo?
   A) endosperm **C)** stigma
   B) pollen grain **D)** root

Use the photo below to answer question 13.



13. What disperses the seeds shown above?
   A) rain **C)** wind
   B) animals **D)** insects
14. What is the series of events that results in a plant growing from a seed?
   A) pollination **C)** germination
   B) prothallus **D)** fertilization
15. In seedless plants, meiosis produces what kind of plant structure?
   A) prothallus **C)** flowers
   B) seeds **D)** spores
16. Ovules and pollen grains take part in what process?
   A) germination
   B) asexual reproduction
   C) seed dispersal
   D) sexual reproduction
17. What part of the flower receives the pollen grain from the anther?
   A) sepal **C)** stamen
   B) petal **D)** stigma

Ed Reschke/Peter Arnold, Inc.
Science Online bookb.msscience.com/vocabulary_puzzlemaker
CONTENTS

Thinking Critically

18. **Explain** why male cones produce so many pollen grains.

19. **Predict** whether a seed without an embryo could germinate. Explain your answer.

20. **Discuss** the importance of water in the sexual reproduction of nonvascular plants and ferns.

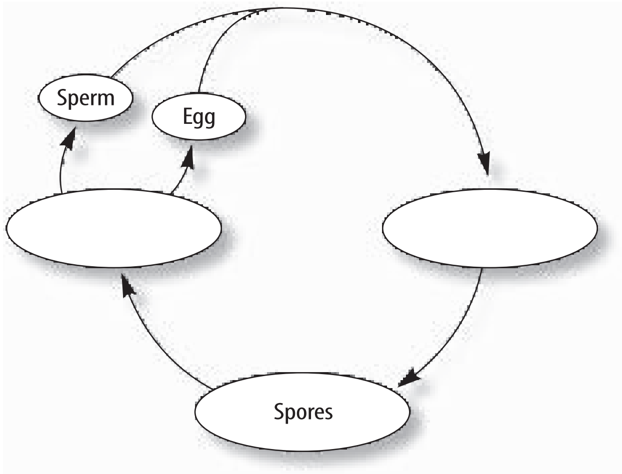
21. **Infer** why the sporophyte stage in mosses is dependent on the gametophyte stage.

22. **List** the features of flowers that ensure pollination.

23. **Compare and contrast** the fern sporophyte and gametophyte stages.

24. **Interpret Scientific Illustrations** Using **Figure 16,** sequence these events.
    - pollen is trapped on the stigma
    - pollen tube reaches the ovule
    - fertilization
    - pollen released from the anther
    - pollen tube forms through the style
    - a seed forms

25. **Concept Map** Copy and complete this concept map of a typical plant life cycle.



26. **Predict** Observe pictures of flowers or actual flowers and predict how they are pollinated. Explain your prediction.

Performance Activities

27. **Display** Collect several different types of seeds and use them to make a mosaic picture of a flower.

28. **Technical Writing** Write a newspaper story to tell people about the importance of gravity, water, wind, insects, and other animals in plant life cycles.

Applying Math

29. **Germination Rates** A seed producer tests a new batch of corn seeds before putting them on the market. The producer plants a sample of 150 seeds, and 110 of the seeds germinate. What is the germination rate for this batch of corn seeds?

30. **Seed Production** Each blossom on an apple tree, if fertilized, can become a fruit. Suppose an apple tree bears 1,200 blossoms in the spring. If 95 percent are pollinated, how many apples could the tree produce? If each apple contains five seeds, how many seeds would the tree produce?

Use the table below to answer question 31.

Onion Seed Data

Temperature (°C)	10	15	20	25	30	35
Days to germinate	13	7	5	4	4	13

31. **Onion Seeds** Make a bar graph for the following data table about onion seeds. Put days on the horizontal axis and temperature on the vertical axis.

chapter 4 Standardized Test Practice

Part 1 Multiple Choice

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

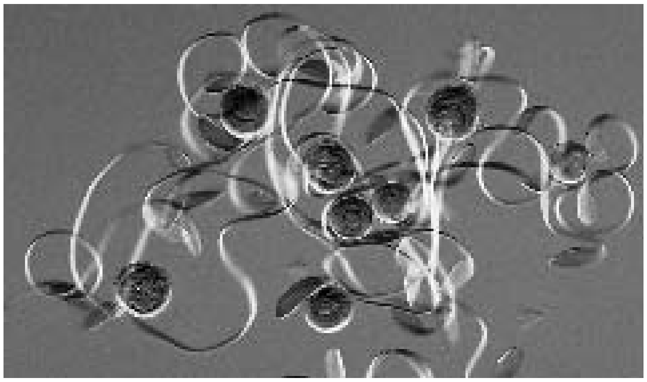
1. Which statement applies to asexual reproduction?

A. Sperm and egg are required.
B. Offspring are genetically different from the parents.
C. Most animals reproduce in this way.
D. Offspring are genetically identical to the parent.

2. Which term describes the uniting of a sperm and egg to form a zygote?

A. fertilization
B. meiosis
C. pollination
D. germination

Use the picture below to answer questions 3 and 4.



3. What is the primary method by which these horsetail spores are dispersed?

A. water
B. insects
C. wind
D. grazing animals

Test-Taking Tip

Come Back To It Never skip a question. If you are unsure of an answer, mark your best guess on another sheet of paper and mark the question in your test booklet to remind you to come back to it at the end of the test.

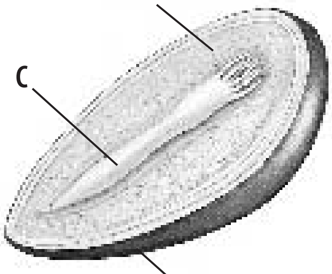
4. The horsetail plant that produced these spores uses tubelike cells to transport water and other substances from one part of the plant to another. What type of plant is a horsetail?

A. vascular
B. seed
C. nonvascular
D. pollinated

5. Which of the following is a characteristic of angiosperms?

A. production of cones
B. seeds not protected by fruit
C. growth from a rhizome
D. production of flowers

Use the illustration below to answer questions 6 and 7.



6. Structure B represents which part of this seed?

A. stored food
B. embryo
C. seed coat
D. ovary

7. Which part(s) of this seed will grow into stems, roots, and leaves?

A. A
B. B
C. C
D. A and B

8. What causes seed germination to begin?

A. warm temperature
B. exposure to water
C. at least 9 hours of daylight in a 24-hour period
D. soil rich in organic material

Andrew Syred/Science Photo Library/Photo Researchers

Part 2 Short Response/Grid In

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

9. Sperm and eggs are found in different parts of plants. Explain why it is important for these cells to unite, and describe some factors in an environment that help unite them.

10. Make a sketch of a fern plant. Label the fronds, rhizome, roots, and sori.

Use the illustration below to answer questions 11 and 12.

11. What type of seed plant produces the structure shown here? Describe how it is involved in the reproduction of this plant.

12. Why are the scales open?

13. Describe the importance of flowers in angiosperms. What factors can differ from one flower to another?

14. Explain the role played by animals that eat fruits in the dispersal and germination of seeds.

15. Describe the characteristics of certain plants, such as grasses, that enable them to be distributed widely in an environment.

Part 3 Open Ended

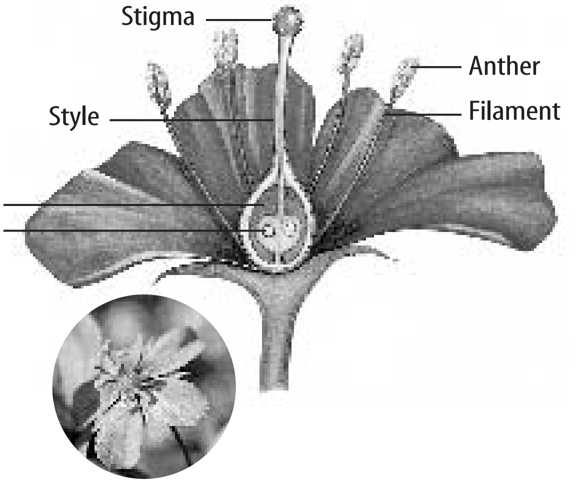
Record your answers on a sheet of paper.

16. You have a holly plant in your yard which, despite having ample water, sunlight, and fertilizer, has never produced berries. The flowers produced by this plant have only female structures. What could you do to help this plant produce berries?

17. Why is it important that spores produced during the gametophyte stage of a plant's life cycle be haploid cells?

18. Describe some of the factors that have contributed to the success of seed plants.

Use the illustration below to answer questions 19 and 20.



19. Describe the role of each structure labeled in this picture in the production of eggs or sperm.

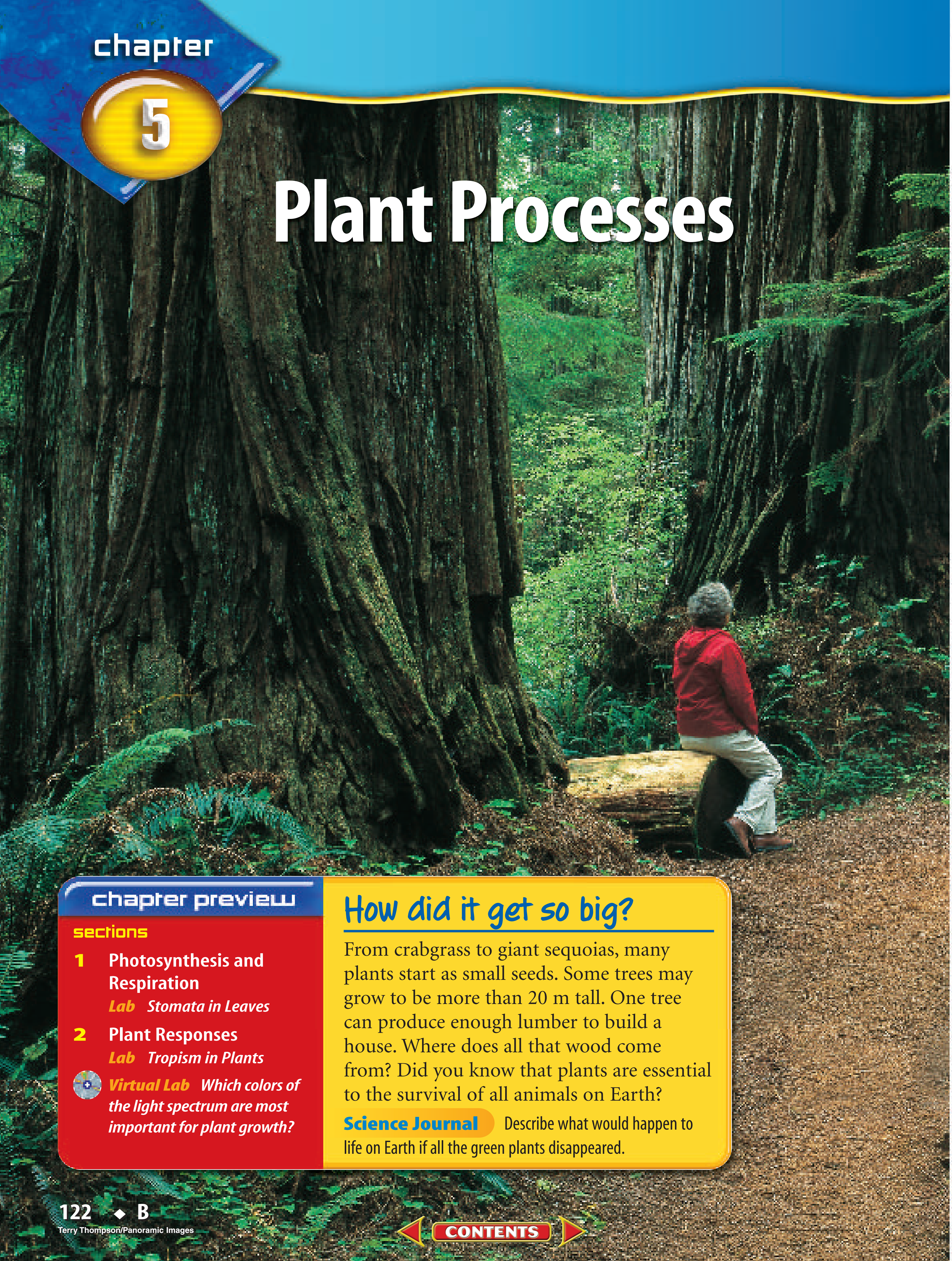
20. Describe the process of pollination of this plant by insects.

21. Explain how a flower's appearance can indicate its method of pollination. Give three examples of flowers and the method of pollination for each.

(l)Dan Suzio/Photo Researchers, (r)Alvin E. Staffan/Photo Researchers

chapter 5

Plant Processes



chapter preview

sections

1. **Photosynthesis and Respiration**
   Lab *Stomata in Leaves*
2. **Plant Responses**
   Lab *Tropism in Plants*

Virtual Lab *Which colors of the light spectrum are most important for plant growth?*

How did it get so big?

From crabgrass to giant sequoias, many plants start as small seeds. Some trees may grow to be more than 20 m tall. One tree can produce enough lumber to build a house. Where does all that wood come from? Did you know that plants are essential to the survival of all animals on Earth?

Science Journal Describe what would happen to life on Earth if all the green plants disappeared.

Terry Thompson/Panoramic Images

CONTENTS

Start-Up Activities

Launch LAB

Do plants lose water?

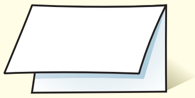
Plants, like all other living organisms, are made of cells, reproduce, and need water to live. What would happen if you forgot to water a houseplant? From your own experiences, you probably know that the houseplant would wilt. Do the following lab to discover one way plants lose water.

1. Obtain a self-sealing plastic bag, some aluminum foil, and a small potted plant from your teacher.
2. Using the foil, carefully cover the soil around the plant in the pot. Place the potted plant in the plastic bag.
3. Seal the bag and place it in a sunny window. Wash your hands.
4. Observe the plant at the same time every day for a few days.
5. **Think Critically** Write a paragraph that describes what happened in the bag. If enough water is lost by a plant and not replaced, predict what will happen to the plant.

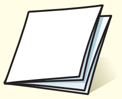
FOLDABLES™ Study Organizer

Photosynthesis and Respiration Make the following Foldable to help you distinguish between photosynthesis and respiration.

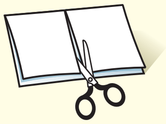
STEP 1 **Fold** a vertical sheet of paper in half from top to bottom.



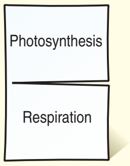
STEP 2 **Fold** in half from side to side with the fold at the top.



STEP 3 **Unfold** the paper once. **Cut** only the fold of the top flap to make two tabs.



STEP 4 **Turn** the paper vertically and **label** the front tabs as shown.



Compare and Contrast As you read the chapter, write the characteristics of respiration and photosynthesis under the appropriate tab.

Science Online | Preview this chapter's content and activities at bookb.msscience.com

CONTENTS

(bkgd)Terry Thompson/Panoramic Images, (c)Matt Meadows

section 1

Photosynthesis and Respiration

as you read

What You'll Learn

- **Explain** how plants take in and give off gases.
- **Compare and contrast** photosynthesis and respiration.
- **Discuss** why photosynthesis and respiration are important.

Why It's Important

Understanding photosynthesis and respiration in plants will help you understand how life exists on Earth.

Review Vocabulary

cellulose: chemical compound made of sugar; forms tangled fibers in plant cell walls and provides structure and support

New Vocabulary

- stomata
- chlorophyll
- photosynthesis
- respiration

Taking in Raw Materials

Sitting in the cool shade under a tree, you eat lunch. Food is one of the raw materials you need to grow. Oxygen is another. It enters your lungs and eventually reaches every cell in your body. Your cells use oxygen to help release energy from the food that you eat. The process that uses oxygen to release energy from food produces carbon dioxide and water as wastes. These wastes move in your blood to your lungs, where they are removed as gases when you exhale. You look up at the tree and wonder, "Does a tree need to eat? Does it use oxygen? How does it get rid of wastes?"

Movement of Materials in Plants Trees and other plants don't take in foods the way you do. Plants make their own foods using the raw materials water, carbon dioxide, and inorganic chemicals in the soil. Just like you, plants also produce waste products.

Most of the water used by plants is taken in through roots, as shown in **Figure 1.** Water moves into root cells and then up through the plant to where it is used. When you pull up a plant, its roots are damaged and some are lost. If you replant it, the plant will need extra water until new roots grow to replace those that were lost.

Leaves, instead of lungs, are where most gas exchange occurs in plants. Most of the water taken in through the roots exits through the leaves of a plant. Carbon dioxide, oxygen, and water vapor exit and enter the plant through openings in the leaf. The leaf's structure helps explain how it functions in gas exchange.

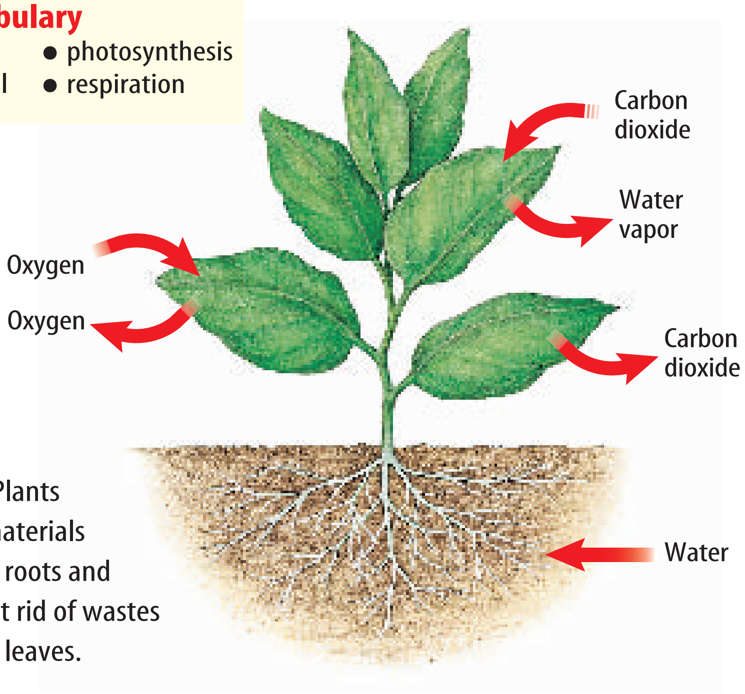
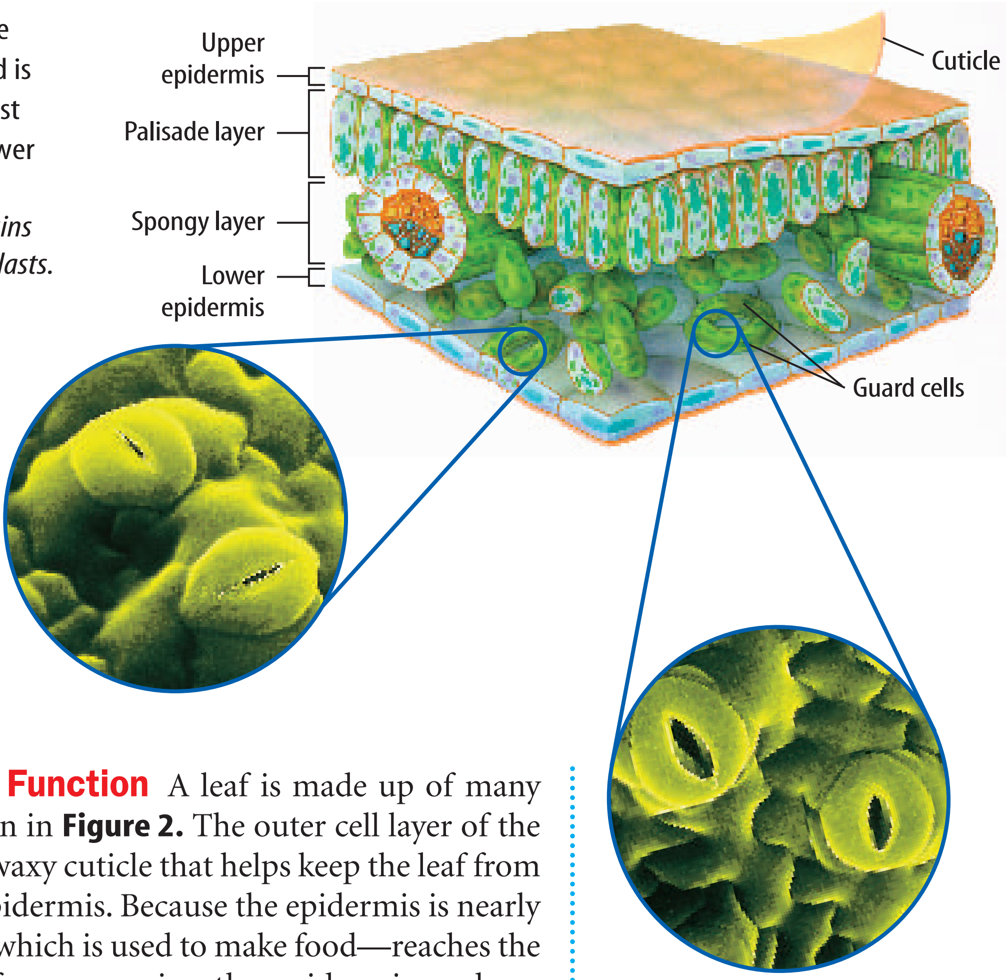


Figure 1 Plants take in raw materials through their roots and leaves and get rid of wastes through their leaves.

Figure 2 A leaf's structure determines its function. Food is made in the inner layers. Most stomata are found on the lower epidermis.
Identify *the layer that contains most of the cells with chloroplasts.*



Leaf Structure and Function A leaf is made up of many different layers, as shown in **Figure 2.** The outer cell layer of the leaf is the epidermis. A waxy cuticle that helps keep the leaf from drying out covers the epidermis. Because the epidermis is nearly transparent, sunlight—which is used to make food—reaches the cells inside the leaf. If you examine the epidermis under a microscope, you will see that it contains many small openings. These openings, called **stomata** (stoh MAH tuh) (singular, *stoma*), act as doorways for raw materials such as carbon dioxide, water vapor, and waste gases to enter and exit the leaf. Stomata also are found on the stems of many plants. More than 90 percent of the water plants take in through their roots is lost through the stomata. In one day, a growing tomato plant can lose up to 1 L of water.

Two cells called guard cells surround each stoma and control its size. As water moves into the guard cells, they swell and bend apart, opening a stoma. When guard cells lose water, they deflate and close the stoma. **Figure 2** shows closed and open stomata.

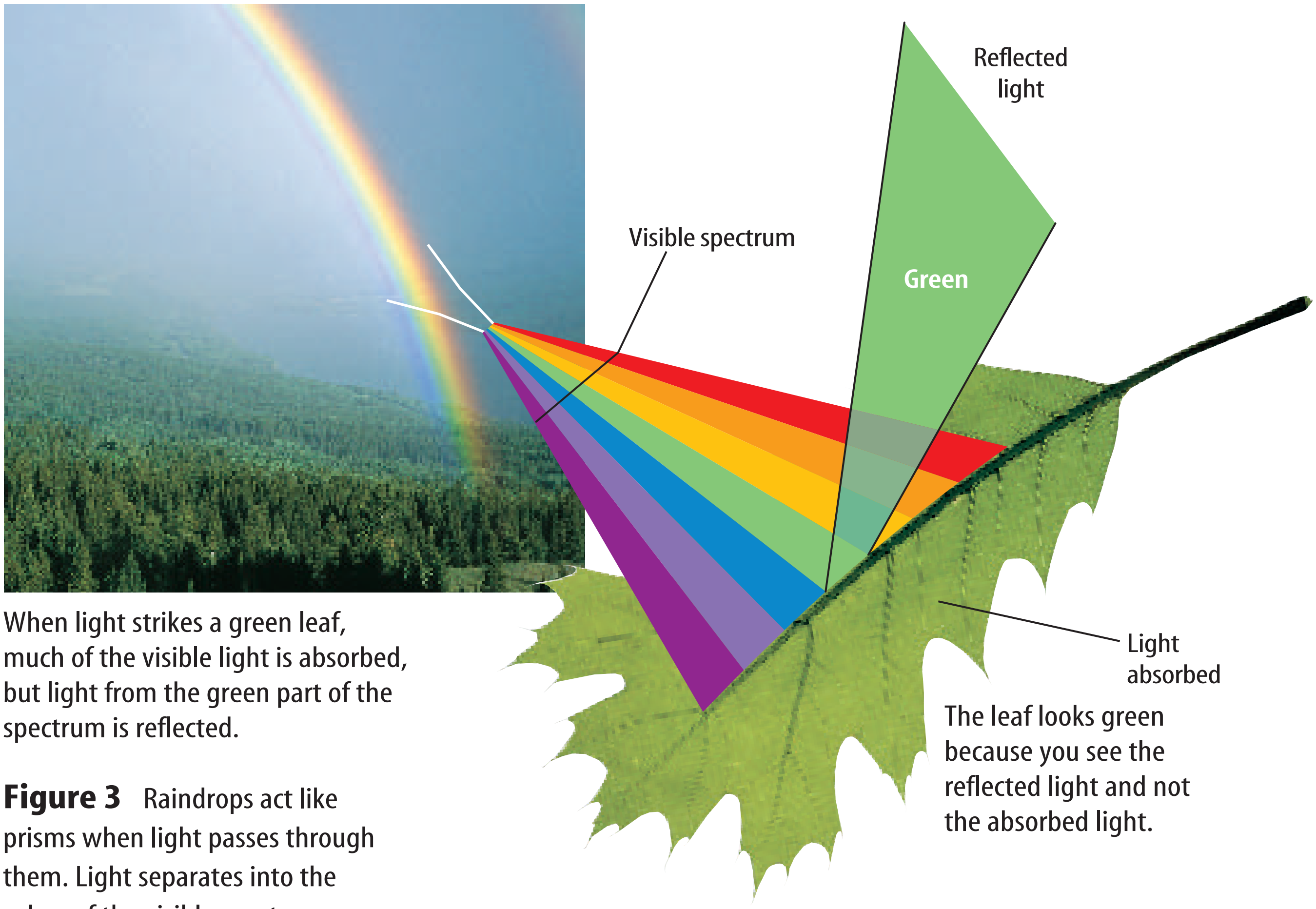
Stomata usually are open during the day, when most plants need to take in raw materials to make food. They usually are closed at night when food making slows down. Stomata also close when a plant is losing too much water. This adaptation conserves water, because less water vapor escapes from the leaf.

Inside the leaf are two layers of cells, the spongy layer and the palisade layer. Carbon dioxide and water vapor, which are needed in the food-making process, fill the spaces of the spongy layer. Most of the plant's food is made in the palisade layer.

INTEGRATE Career

Nutritionist Vitamins are substances needed for good health. Nutritionists promote healthy eating habits. Research to learn about other roles that nutritionists fulfill. Create a pamphlet to promote the career of nutritionist.

Dr. Jeremy Burgess/Science Photo Library/Photo Researchers



When light strikes a green leaf, much of the visible light is absorbed, but light from the green part of the spectrum is reflected.

The leaf looks green because you see the reflected light and not the absorbed light.

Figure 3 Raindrops act like prisms when light passes through them. Light separates into the colors of the visible spectrum. You see a rainbow when this happens.

Chloroplasts and Plant Pigments If you look closely at the leaf in **Figure 2,** you'll see that some of the cells contain small, green structures called chloroplasts. Most leaves look green because some of their cells contain so many chloroplasts. Chloroplasts are green because they contain a green pigment called **chlorophyll** (KLOR uh fihl).

Reading Check *Why are chloroplasts green?*

As shown in **Figure 3,** light from the Sun contains all colors of the visible spectrum. A pigment is a substance that reflects a particular part of the visible spectrum and absorbs the rest. When you see a green leaf, you are seeing green light energy reflected from chlorophyll. Most of the other colors of the spectrum, especially red and blue, are absorbed by chlorophyll. In the spring and summer, most leaves have so much chlorophyll that it hides all other pigments. In fall, the chlorophyll in some leaves breaks down and the leaves change color as other pigments become visible. Pigments, especially chlorophyll, are important to plants because the light energy that they absorb is used to make food. For plants, this food-making process—photosynthesis—happens in the chloroplasts.

(l)John Kieffer/Peter Arnold, Inc., (r)Runk/Schoenberger from Grant Heilman

The Food-Making Process

Photosynthesis (foh toh SIHN thuh suhs) is the process during which a plant's chlorophyll traps light energy and sugars are produced. In plants, photosynthesis occurs only in cells with chloroplasts. For example, photosynthesis occurs only in a carrot plant's lacy green leaves, shown in **Figure 4.** Because a carrot's root cells lack chlorophyll and normally do not receive light, they can't perform photosynthesis. But excess sugar produced in the leaves is stored in the familiar orange root that you and many animals eat.

Besides light, plants also need the raw materials carbon dioxide and water for photosynthesis. The overall chemical equation for photosynthesis is shown below. What happens to each of the raw materials in the process?

$$\underset{\text{carbon dioxide}}{6CO_2} + \underset{\text{water}}{6H_2O} + \text{light energy} \xrightarrow{\text{chlorophyll}} \underset{\text{glucose}}{C_6H_{12}O_6} + \underset{\text{oxygen}}{6O_2}$$

Light-Dependent Reactions Some of the chemical reactions that take place during photosynthesis require light, but others do not. Those that need light can be called the light-dependent reactions of photosynthesis. During light-dependent reactions, chlorophyll and other pigments trap light energy that eventually will be stored in sugar molecules. Light energy causes water molecules, which were taken up by the roots, to split into oxygen and hydrogen. The oxygen leaves the plant through the stomata. This is the oxygen that you breathe. Hydrogen produced when water is split is used in photosynthesis reactions that occur when there is no light.

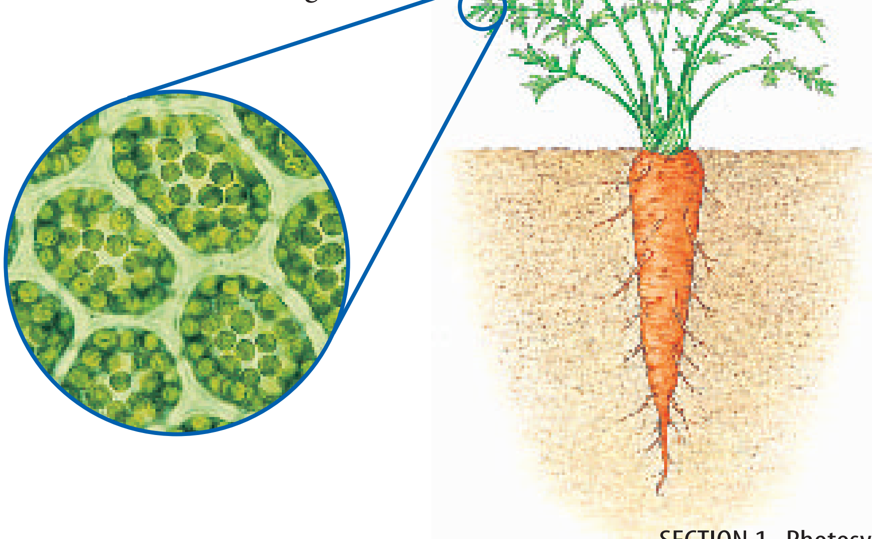


Figure 4 Because they contain chloroplasts, cells in the leaf of the carrot plant are the sites for photosynthesis.

M. Eichelberger/Visuals Unlimited

Mini LAB

Inferring What Plants Need to Produce Chlorophyll

Procedure

1. Cut two pieces of **black construction paper** large enough so that each one completely covers one leaf on a **plant**.
2. Cut a square out of the center of each piece of paper.
3. Sandwich the leaf between the two paper pieces and **tape** the pieces together along their edges.
4. Place the plant in a sunny area. Wash your hands.
5. After seven days, carefully remove the paper and observe the leaf.

Analysis

In your **Science Journal,** describe how the color of the areas covered by paper compare to the areas not covered. Infer why this happened.

Try at Home

Science*Online*

Topic: Plant Sugars

Visit bookb.msscience.com for Web links to information about sugars and related molecules produced by plants.

Activity List three sugar-containing molecules that plants produce.

Light-Independent Reactions Reactions that don't need light are called the light-independent reactions of photosynthesis. Carbon dioxide, the raw material from the air, is used in these reactions. The light energy trapped during the light-dependent reactions is used to combine carbon dioxide and hydrogen to make sugars. One important sugar that is made is glucose. The chemical bonds that hold glucose and other sugars together are stored energy. **Figure 5** compares what happens during each stage of photosynthesis.

What happens to the oxygen and glucose that were made during photosynthesis? Most of the oxygen from photosynthesis is a waste product and is released through stomata. Glucose is the main form of food for plant cells. A plant usually produces more glucose than it can use. Excess glucose is stored in plants as other sugars and starches. When you eat carrots, as well as beets, potatoes, or onions, you are eating the stored product of photosynthesis.

Glucose also is the basis of a plant's structure. You don't grow larger by breathing in and using carbon dioxide. However, that's exactly what plants do as they take in carbon dioxide gas and convert it into glucose. Cellulose, an important part of plant cell walls, is made from glucose. Leaves, stems, and roots are made of cellulose and other substances produced using glucose. The products of photosynthesis are used for plant growth.

Figure 5 Photosynthesis includes two sets of reactions, the light-dependent reactions and the light-independent reactions.
Describe *what happens to the glucose produced during photosynthesis.*

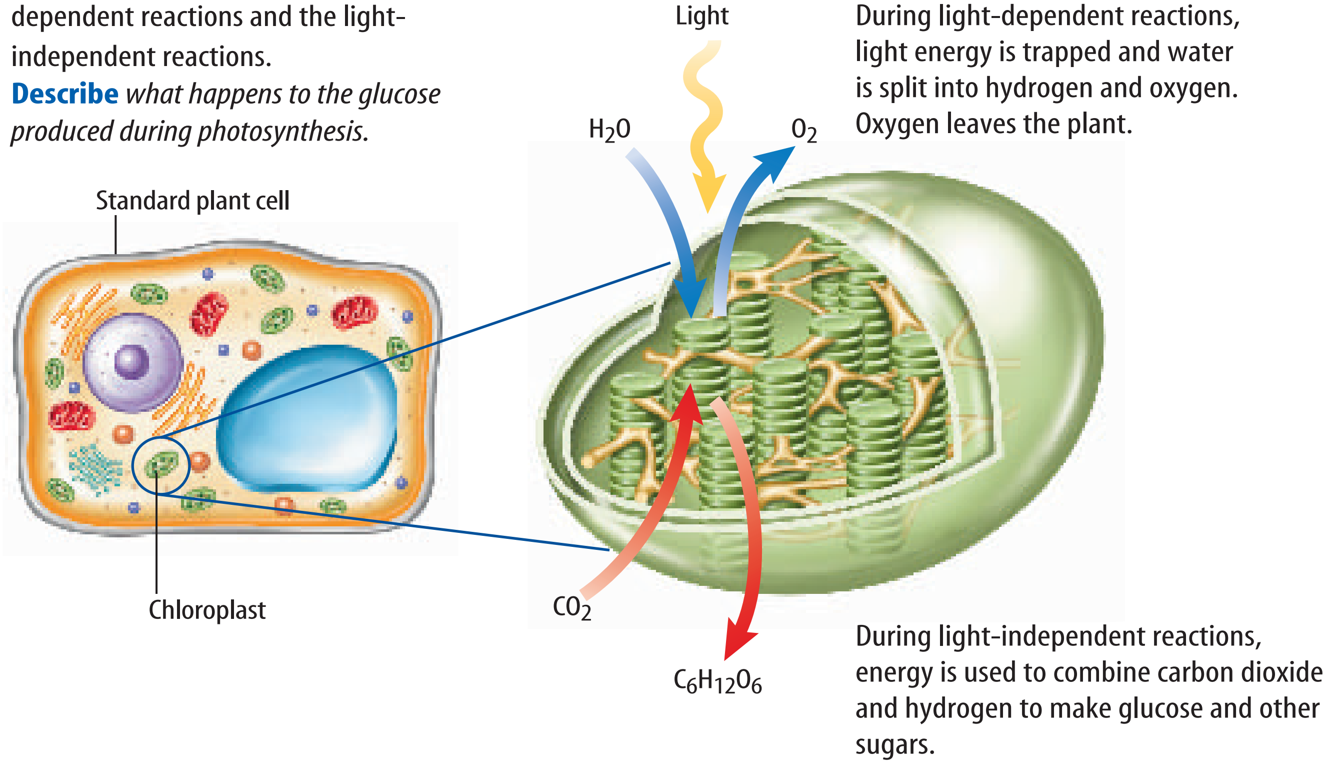


Figure 6 Tropical rain forests contain large numbers of photosynthetic plants.
Infer *why tropical forests are considered an important source of oxygen.*

Importance of Photosynthesis Why is photosynthesis important to living things? First, photosynthesis produces food. Organisms that carry on photosynthesis provide food directly or indirectly for nearly all the other organisms on Earth. Second, photosynthetic organisms, like the plants in **Figure 6,** use carbon dioxide and release oxygen. This removes carbon dioxide from the atmosphere and adds oxygen to it. Most organisms, including humans, need oxygen to stay alive. As much as 90 percent of the oxygen entering the atmosphere today is a result of photosynthesis.

The Breakdown of Food

Look at the photograph in **Figure 7.** Do the fox and the plants in the photograph have anything in common? They don't look alike, but the fox and the plants are made of cells that break down food and release energy in a process called respiration. How does this happen?

Respiration is a series of chemical reactions that breaks down food molecules and releases energy. Respiration occurs in cells of most organisms. The breakdown of food might or might not require oxygen. Respiration that uses oxygen to break down food chemically is called aerobic respiration. In plants and many organisms that have one or more cells, a nucleus, and other organelles, aerobic respiration occurs in the mitochondria (singular, *mitochondrion*). The overall chemical equation for aerobic respiration is shown below.

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + \text{energy}$$

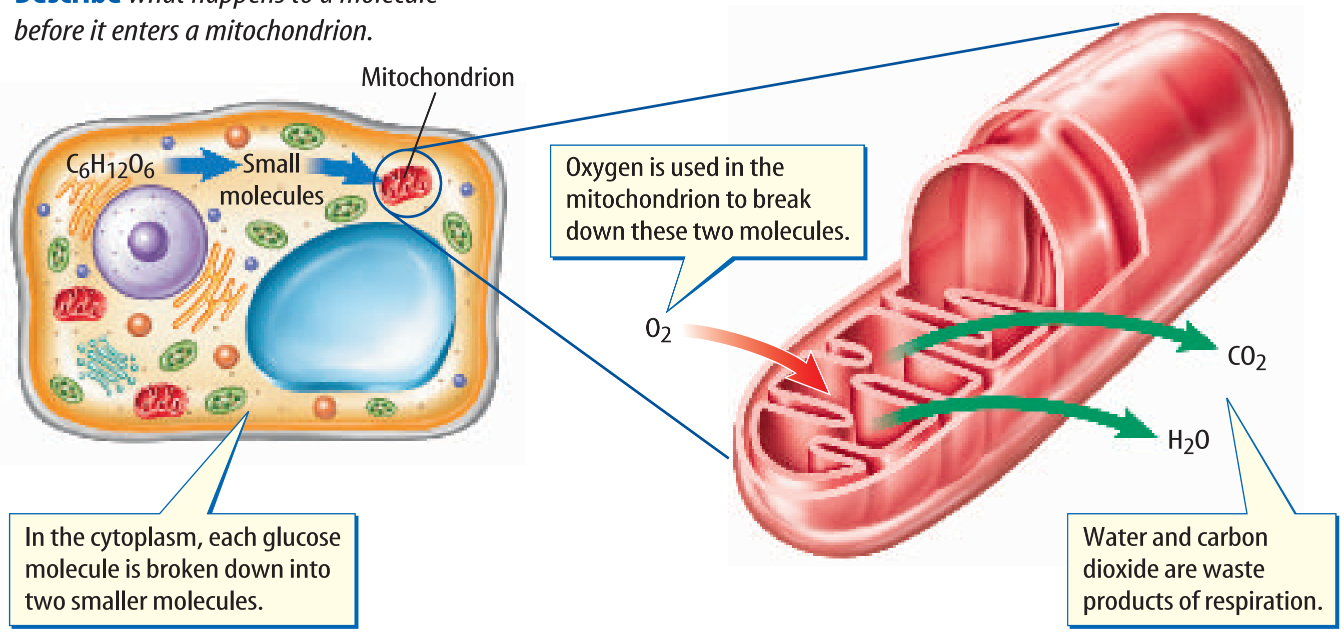
glucose, oxygen, carbon dioxide, water

Figure 7 You know that animals such as this red fox carry on respiration, but so do all the plants that surround the fox.

CONTENTS

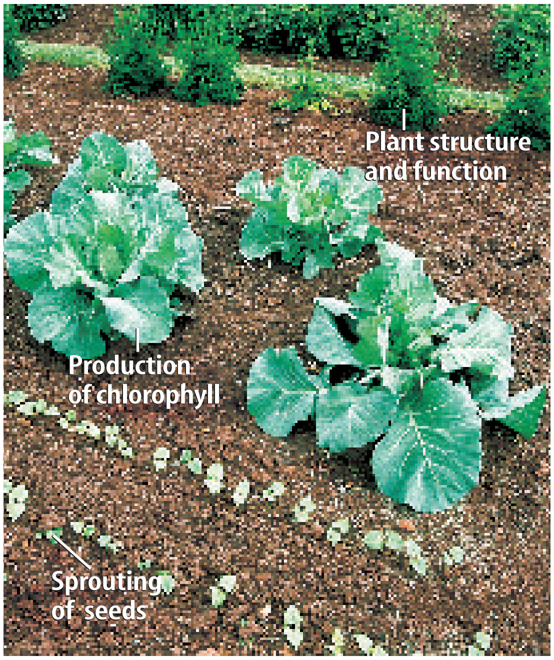
(t)Jacques Jangoux/Peter Arnold, Inc., (b)Jeff Lepore/Photo Researchers

Figure 8 Aerobic respiration takes place in the mitochondria of plant cells.
Describe *what happens to a molecule before it enters a mitochondrion.*



Aerobic Respiration Before aerobic respiration begins, glucose molecules are broken down into two smaller molecules. This happens in the cytoplasm. The smaller molecules then enter a mitochondrion, where aerobic respiration takes place. Oxygen is used in the chemical reactions that break down the small molecules into water and carbon dioxide. The reactions also release energy. Every cell in the organism needs this energy. **Figure 8** shows aerobic respiration in a plant cell.

Figure 9 Plants use the energy released during respiration to carry out many functions.



Importance of Respiration Although food contains energy, it is not in a form that can be used by cells. Respiration changes food energy into a form all cells can use. This energy drives the life processes of almost all organisms on Earth.

Reading Check *What organisms use respiration?*

Plants use energy produced by respiration to transport sugars and to open and close stomata. Some of the energy is used to produce substances needed for photosynthesis, such as chlorophyll. When seeds sprout, they use energy from the respiration of stored food in the seed. **Figure 9** shows some uses of energy in plants.

The waste product carbon dioxide is also important. Aerobic respiration returns carbon dioxide to the atmosphere, where it can be used again by plants and some other organisms for photosynthesis.

Michael P. Gadomski/Photo Researchers

Table 1 Comparing Photosynthesis and Aerobic Respiration

	Energy	Raw Materials	End Products	Where
Photosynthesis	stored	water and carbon dioxide	glucose and oxygen	cells with chlorophyll
Aerobic respiration	released	glucose and oxygen	water and carbon dioxide	cells with mitochondria

Comparison of Photosynthesis and Respiration

Look back in the section to find the equations for photosynthesis and aerobic respiration. You can see that aerobic respiration is almost the reverse of photosynthesis. Photosynthesis combines carbon dioxide and water by using light energy. The end products are glucose (food) and oxygen. During photosynthesis, energy is stored in food. Photosynthesis occurs only in cells that contain chlorophyll, such as those in the leaves of plants. Aerobic respiration combines oxygen and food to release the energy in the chemical bonds of the food. The end products of aerobic respiration are energy, carbon dioxide, and water. All plant cells contain mitochondria. Any cell with mitochondria can use the process of aerobic respiration. **Table 1** compares photosynthesis and aerobic respiration.

section 1 review

Summary

Taking in Raw Materials

- Leaves take in carbon dioxide that is used in photosynthesis.
- Oxygen and carbon dioxide are waste products of photosynthesis and respiration.

The Food-Making Process

- Photosynthesis takes place in chloroplasts.
- Photosynthesis is a series of chemical reactions that transforms energy from light into energy stored in the chemical bonds of sugar molecules.

The Breakdown of Food

- Aerobic respiration uses oxygen to release energy from food.
- Aerobic respiration takes place in mitochondria.

Self Check

1. **Describe** how gases enter and exit a leaf.
2. **Explain** why photosynthesis and respiration are important.
3. **Identify** what must happen to glucose molecules before respiration begins.
4. **Compare and contrast** the number of organisms that respire and the number that photosynthesize.
5. **Think Critically** Humidity is water vapor in the air. Infer how plants contribute to humidity.

Applying Math

6. **Solve One-Step Equations** How many CO_2 molecules result from the respiration of a glucose molecule ($C_6H_{12}O_6$)? Refer to the equation in this section.

Science Online bookb.msscience.com/self_check_quiz

CONTENTS

LAB

Stomata in Leaves

Stomata open and close, which allows gases into and out of a leaf. These openings are usually invisible without the use of a microscope. Do this lab to see some stomata.

Real-World Question

Where are stomata in lettuce leaves?

Goals

- **Describe** guard cells and stomata.
- **Infer** the conditions that make stomata open and close.

Materials

lettuce in dish of water
coverslip
microscope
microscope slide
salt solution
forceps

Safety Precautions

WARNING: *Never eat or taste any materials used in the laboratory.*

Procedure

1. Copy the Stomata Data table into your Science Journal.
2. From a head of lettuce, tear off a piece of an outer, crisp, green leaf.
3. Bend the piece of leaf in half and carefully use a pair of forceps to peel off some of the epidermis, the transparent tissue that covers a leaf. Prepare a wet mount of this tissue.
4. Examine your prepared slide under low and high power on the microscope.
5. Count the total number of stomata in your field of view and then count the number of open stomata. Enter these numbers in the data table.
6. Make a second slide of the lettuce leaf epidermis. This time place a few drops of salt solution on the leaf instead of water.
7. Repeat steps 4 and 5.
8. **Calculate** the percent of open stomata using the following equation:

$$\frac{\text{number of open stomata}}{\text{total number of stomata}} \times 100 = \text{percent open}$$

Stomata Data (Sample data only)

	Wet Mount	Salt-Solution Mount
Total Number of Stomata		
Number of Open Stomata	Do not write in this book.	
Percent Open		

Conclude and Apply

1. **Determine** which slide preparation had a greater percentage of open stomata.
2. **Infer** why fewer stomata were open in the salt-solution mount.
3. What can you infer about the function of stomata in a leaf?

Communicating Your Data

Collect data from your classmates and compare it to your data. Discuss any differences you find and why they occurred. **For more help, refer to the Science Skill Handbook.**

section 2

Plant Responses

What are plant responses?

It's dark. You're alone in a room watching a horror film on television. Suddenly, the telephone near you rings. You jump, and your heart begins to beat faster. You've just responded to a stimulus. A stimulus is anything in the environment that causes a response in an organism. The response often involves movement either toward the stimulus or away from the stimulus. A stimulus may come from outside (external) or inside (internal) the organism. The ringing telephone is an example of an external stimulus. It caused you to jump, which is a response. Your beating heart is a response to an internal stimulus. Internal stimuli are usually chemicals produced by organisms. Many of these chemicals are hormones. Hormones are substances made in one part of an organism for use somewhere else in the organism.

All living organisms, including plants, respond to stimuli. Many different chemicals are known to act as hormones in plants. These internal stimuli have a variety of effects on plant growth and function. Plants respond to external stimuli such as touch, light, and gravity. Some responses, such as the response of the Venus's-flytrap plant in **Figure 10,** are rapid. Other plant responses are slower because they involve changes in growth.

as you read

What You'll Learn

- **Identify** the relationship between a stimulus and a tropism in plants.
- **Compare and contrast** long-day and short-day plants.
- **Explain** how plant hormones and responses are related.

Why It's Important

You will be able to grow healthier plants if you understand how they respond to certain stimuli.

Review Vocabulary

behavior: the way in which an organism interacts with other organisms and its environment

New Vocabulary

- tropism
- auxin
- photoperiodism
- long-day plant
- short-day plant
- day-neutral plant

Figure 10 A Venus's-flytrap has three small trigger hairs on the surface of its toothed leaves. When two hairs are touched at the same time, the plant responds by closing its trap in less than 1 second.

Howard Miller/Photo Researchers

Figure 11 Tropisms are responses to external stimuli.
Identify *the part of a plant that shows negative gravitropism.*

The pea plant's tendrils respond to touch by coiling around things.

This plant is growing toward the light, an example of positive phototropism.

This plant was turned on its side. With the roots visible, you can see that they are showing positive gravitropism.

Tropisms

Some responses of a plant to an external stimuli are called tropisms. A **tropism** (TROH pih zum) can be seen as movement caused by a change in growth and can be positive or negative. For example, plants might grow toward a stimulus—a positive tropism—or away from a stimulus—a negative tropism.

Touch One stimulus that can result in a change in a plant's growth is touch. When the pea plant, as shown in **Figure 11,** touches a solid object, it responds by growing faster on one side of its stem than on the other side. As a result the stem bends and twists around any object it touches.

Light Did you ever see a plant leaning toward a window? Light is an important stimulus to plants. When a plant responds to light, the cells on the side of the plant opposite the light get longer than the cells facing the light. Because of this uneven growth, the plant bends toward the light. This response causes the leaves to turn in such a way that they can absorb more light. When a plant grows toward light it is called a positive response to light, or positive phototropism, shown in **Figure 11.**

Gravity Plants respond to gravity. The downward growth of plant roots, as shown in **Figure 11,** is a positive response to gravity. A stem growing upward is a negative response to gravity. Plants also may respond to electricity, temperature, and darkness.

INTEGRATE Physics

Gravity and Plants
Gravity is a stimulus that affects how plants grow. Can plants grow without gravity? In space the force of gravity is low. Write a paragraph in your Science Journal that describes your idea for an experiment aboard a space shuttle to test how low gravity affects plant growth.

(l)Scott Camazine/Photo Researchers, (c,r)Matt Meadows

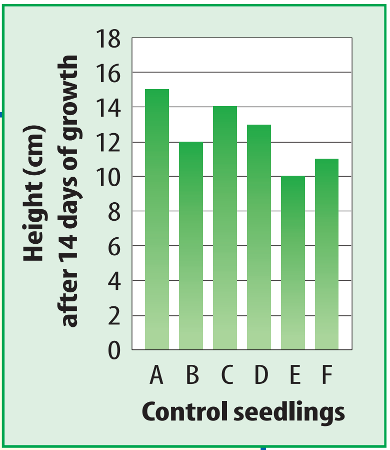
Plant Hormones

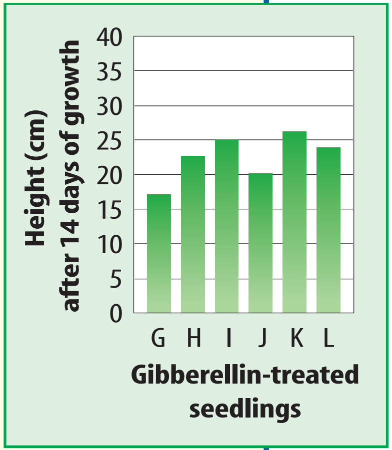
Hormones control the changes in growth that result from tropisms and affect other plant growth. Plants often need only millionths of a gram of a hormone to stimulate a response.

Ethylene Many plants produce the hormone ethylene (EH thuh leen) gas and release it into the air around them. Ethylene is produced in cells of ripening fruit, which stimulates the ripening process. Commercially, fruits such as oranges and bananas are picked when they are unripe and the green fruits are exposed to ethylene during shipping so they will ripen. Another plant response to ethylene causes a layer of cells to form between a leaf and the stem. The cell layer causes the leaf to fall from the stem.

Applying Math — Calculate Averages

GROWTH HORMONES Gibberellins are plant hormones that increase growth rate. The graphs on the right show data from an experiment to determine how gibberellins affect the growth of bean seedlings. What is the average height of control bean seedlings after 14 days?





Solution

1. *This is what you know:*
   - height of control seedlings after 14 days
   - number of control seedlings
2. *This is what you need to find out:* What is the average height of control seedlings after 14 days?
3. *This is the procedure you need to use:*
   - Find the total of the seedling heights. 15 + 12 + 14 + 13 + 10 + 11 = 75 cm
   - Divide the height total by the number of control seedlings to find the average height. 75 cm/6 = 12.5 cm
4. *Check your answer:* Multiply 12.5 cm by 6 and you should get 75 cm.

Practice Problems

1. Calculate the average height of seedlings treated with gibberellin.
2. In an experiment, the heights of gibberellin-treated rose stems were 20, 26, 23, 24, 23, 25, and 26 cm. The average height of the controls was 23 cm. Did gibberellin have an effect?

Science Online
For more practice, visit bookb.msscience.com/math_practice

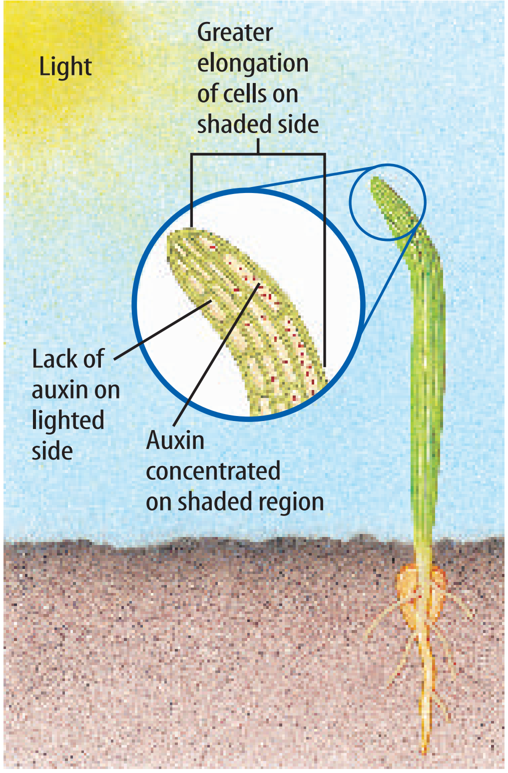


Figure 12 The concentration of auxin on the shaded side of a plant causes cells on that side to lengthen.

Mini LAB

Observing Ripening

Procedure

1. Place a **green banana** in a **paper bag.** Roll the top shut.
2. Place another green banana on a counter or table.
3. After two days check the bananas to see how they have ripened. **WARNING:** *Do not eat the materials used in the lab.*

Analysis

Which banana ripened more quickly? Why?

Try at Home

Auxin Scientists identified the plant hormone, **auxin** (AWK sun) more than 100 years ago. Auxin is a type of plant hormone that causes plant stems and leaves to exhibit positive response to light. When light shines on a plant from one side, the auxin moves to the shaded side of the stem where it causes a change in growth, as shown in **Figure 12.** Auxins also control the production of other plant hormones, including ethylene.

Reading Check *How are auxins and positive response to light related?*

Development of many parts of the plant, including flowers, roots, and fruit, is stimulated by auxins. Because auxins are so important in plant development, synthetic auxins have been developed for use in agriculture. Some of these synthetic auxins are used in orchards so that all plants produce flowers and fruit at the same time. Other synthetic auxins damage plants when they are applied in high doses and are used as weed killers.

Gibberellins and Cytokinins Two other groups of plant hormones that also cause changes in plant growth are gibberellins and cytokinins. Gibberellins (jih buh REH lunz) are chemical substances that were isolated first from a fungus. The fungus caused a disease in rice plants called "foolish seedling" disease. The fungus infects the stems of plants and causes them to grow too tall. Gibberellins can be mixed with water and sprayed on plants and seeds to stimulate plant stems to grow and seeds to germinate.

Like gibberellins, cytokinins (si tuh KI nunz) also cause rapid growth. Cytokinins promote growth by causing faster cell divisions. Like ethylene, the effect of cytokinins on the plant also is controlled by auxin. Interestingly, cytokinins can be sprayed on stored vegetables to keep them fresh longer.

Abscisic Acid Because hormones that cause growth in plants were known to exist, biologists suspected that substances that have the reverse effect also must exist. Abscisic (ab SIH zihk) acid is one such substance. Many plants grow in areas that have cold winters. Normally, if seeds germinate or buds develop on plants during the winter, they will die. Abscisic acid is the substance that keeps seeds from sprouting and buds from developing during the winter. This plant hormone also causes stomata to close and helps plants respond to water loss on hot summer days. **Figure 13** summarizes how plant hormones affect plants and how hormones are used.

NATIONAL GEOGRAPHIC

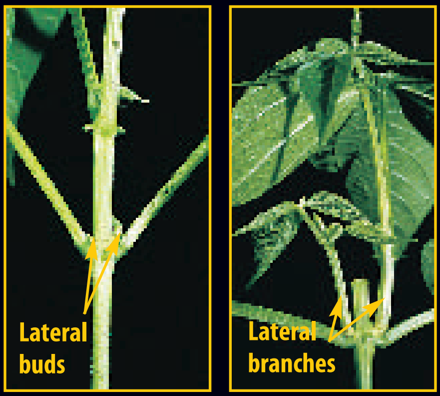
VISUALIZING PLANT HORMONES

Figure 13

Chemical compounds called plant hormones help determine how a plant grows. There are five main types of hormones. They coordinate a plant's growth and development, as well as its responses to environmental stimuli, such as light, gravity, and changing seasons. Most changes in plant growth are a result of plant hormones working together, but exactly how hormones cause these changes is not completely understood.

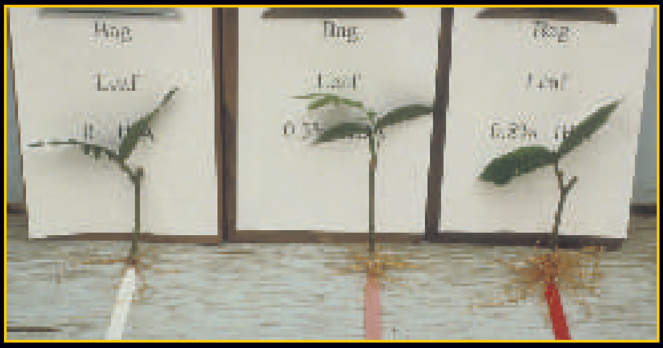
▲ **ETHYLENE** By controlling the exposure of these tomatoes to ethylene, a hormone that stimulates fruit ripening, farmers are able to harvest unripe fruit and make it ripen just before it arrives at the supermarket.

◀ **GIBBERELLINS** The larger mustard plant in the photo at left was sprayed with gibberellins, plant hormones that stimulate stem elongation and fruit development.



◀ **CYTOKININS** Lateral buds do not usually develop into branches. However, if a plant's main stem is cut, as in this bean plant, naturally occurring cytokinins will stimulate the growth of lateral branches, causing the plant to grow "bushy."

▼ **AUXINS** Powerful growth hormones called auxins regulate responses to light and gravity, stem elongation, and root growth. The root growth on the plant cuttings, center and right, is the result of auxin treatment.



▶ **ABA (ABSCISIC ACID)** In plants such as the American basswood, right, abscisic acid causes buds to remain dormant for the winter. When spring arrives, ABA stops working and the buds sprout.

(t)Artville, (c... /Sc... (c... Malcolm B. Wilkins/University of Glasgow, (bl)Eric Brenna, (br)John Sohlden/Visuals Unlimited

Science Online

Topic: Plant Pigments

Visit bookb.msscience.com for Web links to information about how plant pigments are involved in photoperiodism.

Activity Explain how day length affects a hormone that promotes flowering.

Photoperiods

INTEGRATE Earth Science

Sunflowers bloom in the summer, and cherry trees flower in the spring. Some plant species produce flowers at specific times during the year. A plant's response to the number of hours of daylight and darkness it receives daily is **photoperiodism** (foh toh PIHR ee uh dih zum).

Earth revolves around the Sun once each year. As Earth moves in its orbit, it also rotates. One rotation takes about 24 h. Because Earth is tilted about 23.5° from a line perpendicular to its orbit, the hours of daylight and darkness vary with the seasons. As you probably have noticed, the Sun sets later in summer than in winter. These changes in lengths of daylight and darkness affect plant growth.

Darkness and Flowers Many plants require a specific length of darkness to begin the flowering process. Generally, plants that require less than 10 h to 12 h of darkness to flower are called **long-day plants.** You may be familiar with some long-day plants such as spinach, lettuce, and beets. Plants that need 12 or more hours of darkness to flower are called **short-day plants.** Some short-day plants are poinsettias, strawberries, and ragweed. **Figure 14** shows what happens when a short-day plant receives less darkness than it needs to flower.

Reading Check *What is needed to begin the flowering process?*

Day-Neutral Plants Plants like dandelions and roses are **day-neutral plants.** They have no specific photoperiod, and the flowering process can begin within a range of hours of darkness.

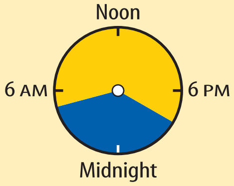
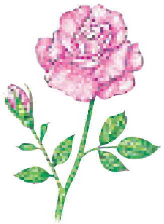
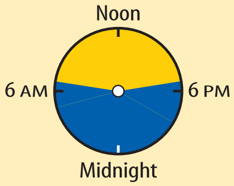
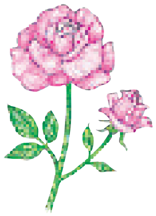
In nature, photoperiodism affects where flowering plants can grow and produce flowers and fruit. Even if a particular environment has the proper temperature and other growing conditions for a plant, it will not flower and produce fruit without the correct photoperiod. **Table 2** shows how day length affects flowering in all three types of plants.

Sometimes the photoperiod of a plant has a narrow range. For example, some soybeans will flower with 9.5 h of darkness but will not flower with 10 h of darkness. Farmers must choose the variety of soybeans with a photoperiod that matches the hours of darkness in the section of the country where they plant their crop.

Figure 14 When short-day plants receive less darkness than required to produce flowers, they produce larger leaves instead.

Jim Metzger

Table 2 Photoperiodism

	Long-Day Plants	Short-Day Plants	Day-Neutral Plants
Early Summer 			
Late Fall 			
	An iris is a long-day plant that is stimulated by short nights to flower in the early summer.	Goldenrod is a short-day plant that is stimulated by long nights to flower in the fall.	Roses are day-neutral plants and have no specific photoperiod.

Today, greenhouse growers are able to provide any length of artificial daylight or darkness. This means that you can buy short-day flowering plants during the summer and long-day flowering plants during the winter.

section 2 review

Summary

What are plant responses?

- Plants respond to both internal and external stimuli.

Tropisms

- Tropisms are plant responses to external stimuli, including touch, light, and gravity.

Plant Hormones

- Hormones control changes in plant growth, including changes that result from tropisms.

Photoperiods

- Long-day plants flower in late spring or summer.
- Short-day plants flower in late fall or winter.

Self Check

1. **List** one example of an internal stimulus and one example of an external stimulus in plants.
2. **Compare and contrast** photoperiodism and phototropism.
3. **Identify** the term that describes the photoperiod of red raspberries that produce fruit in late spring and in the fall.
4. **Distinguish** between abscisic acid and gibberellins.
5. **Think Critically** Describe the relationship between hormones and tropisms.

Applying Skills

6. **Compare and contrast** the responses of roots and stems to gravity.

LAB

Tropism in Plants

Goals

- **Describe** how roots and stems respond to gravity.
- **Observe** how changing the stimulus changes the growth of plants.

Materials

paper towel
30-cm × 30-cm sheet of aluminum foil
water
mustard seeds
marking pen
1-L clear-glass or plastic jar

Safety Precautions

WARNING: *Some kinds of seeds are poisonous. Do not put any seed in your mouth.*

Real-World Question

Grapevines can climb on trees, fences, or other nearby structures. This growth is a response to the stimulus of touch. Tropisms are specific plant responses to stimuli outside of the plant. One part of a plant can respond positively while another part of the same plant can respond negatively to the same stimulus. Gravitropism is a response to gravity. Why might it be important for some plant parts to have a positive response to gravity while other plant parts have a negative response? Do stems and roots respond to gravity in the same way? You can design an experiment to test how some plant parts respond to the stimulus of gravity.

(t)Ed Reschke/Peter Arnold, Inc., (b)Matt Meadows

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Procedure

1. Copy the data table on the right in your Science Journal.
2. Moisten the paper towel with water so that it's damp but not dripping. Fold it in half twice.
3. Place the folded paper towel in the center of the foil and sprinkle mustard seeds in a line across the center of the towel.
4. Fold the foil around the towel and seal each end by folding the foil over. Make sure the paper towel is completely covered by the foil.
5. Use a marking pen to draw an arrow on the foil, and place the foil package in the jar with the arrow pointing upward.
6. After five days, carefully open the package and record your observations in the data table. (Note: *If no stems or roots are growing yet, reseal the package and place it back in the jar, making sure that the arrow points upward. Reopen the package in two days.*)
7. Reseal the foil package, being careful not to disturb the seedlings. Place it in the jar so that the arrow points downward instead of upward.
8. After five more days, reopen the package and observe any new growth of the seedlings' roots and stems. Record your observations in your data table.

Response to Gravity

Position of Arrow on Foil Package	Observations of Seedling Roots	Observations of Seedling Stems
Arrow up	Do not write in this book.	
Arrow down		

Analyze Your Data

1. **Classify** the responses you observed as positive or negative tropisms.
2. **Explain** why the plants' growth changed when you placed them upside down.

Conclude and Apply

1. **Infer** why it was important that no light reach the seedlings during your experiment.
2. **Describe** some other ways you could have changed the position of the foil package to test the seedlings' response.

Communicating Your Data

Compare drawings you make of the growth of the seedlings before and after you turned the package. **Compare** your drawings with those of other students in your class. **For more help, refer to the Science Skill Handbook.**

Matt Meadows

"Sunkissed: An Indian Legend"

as told by Alberto and Patricia De La Fuente

A long time ago, deep down in the very heart of the old Mexican forests, so far away from the sea that not even the largest birds ever had time to fly that far, there was a small, beautiful valley. A long chain of snow-covered mountains stood between the valley and the sea. . . . Each day the mountains were the first ones to tell everybody that Tonatiuh, the King of Light, was coming to the valley. . . .

"Good morning, Tonatiuh!" cried a little meadow. . . .

The wild flowers always started their fresh new day with a kiss of golden sunlight from Tonatiuh, but it was necessary to first wash their sleepy baby faces with the dew that Metztli, the Moon, sprinkled for them out of her bucket onto the nearby leaves during the night. . . .

. . . All night long, then, Metztli Moon would walk her night-field making sure that by sun-up all flowers had the magic dew that made them feel beautiful all day long.

However, much as flowers love to be beautiful as long as possible, they want to be happy too. So every morning Tonatiuh himself would give each one a single golden kiss of such power that it was possible to be happy all day long after it. As you can see, then, a flower needs to feel beautiful in the first place, but if she does not feel beautiful, she will not be ready for her morning sun-kiss. If she cannot wash her little face with the magic dew, the whole day is lost.

Understanding Literature

Legends and Oral Traditions A legend is a traditional story often told orally and believed to be based on actual people and events. Legends are believed to be true even if they cannot be proved. "Sunkissed: An Indian Legend" is a legend about a little flower that is changed forever by the Sun. This legend also is an example of an oral tradition. Oral traditions are stories or skills that are handed down by word of mouth. What in this story indicates that it is a legend?

Respond to the Reading

1. What does this passage tell you about the relationship between the Sun and plants?
2. What does this passage tell you about the relationship between water and the growth of flowers?
3. **Linking Science and Writing** Create an idea for a fictional story that explains why the sky becomes so colorful during a sunset. Then retell your story to your classmates.

INTEGRATE Life Science The passage from "Sunkissed: An Indian Legend" does not teach us the details about photosynthesis or respiration. However, it does show how sunshine and water are important to plant life. The difference between the legend and the information contained in your textbook is this—photosynthesis and respiration can be proved scientifically, and the legend, although fun to read, cannot.

Greg Vaughn/Getty Images

chapter 5 Study Guide

Reviewing Main Ideas

Section 1 Photosynthesis and Respiration

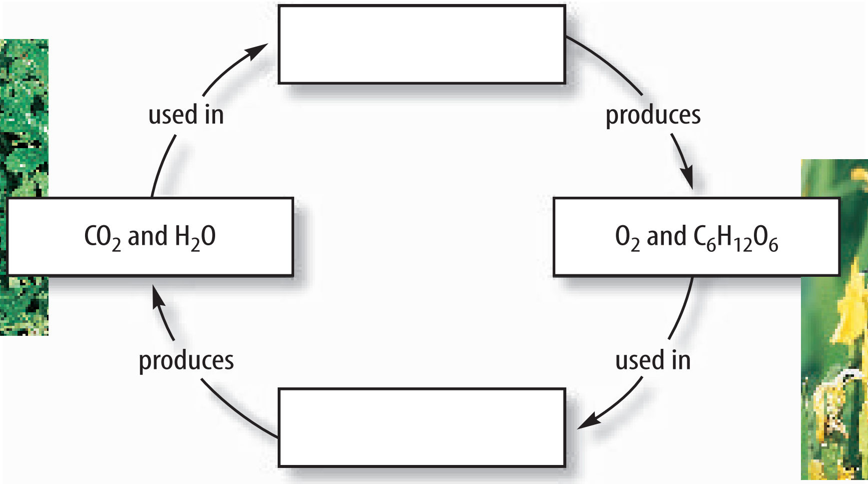
1. Carbon dioxide and water vapor enter and leave a plant through openings in the epidermis called stomata. Guard cells cause a stoma to open and close.
2. Photosynthesis takes place in the chloroplasts of plant cells. Light energy is used to produce glucose and oxygen from carbon dioxide and water.
3. Photosynthesis provides the food for most organisms on Earth.
4. All organisms use respiration to release the energy stored in food molecules. Oxygen is used in the mitochondria to complete respiration in plant cells and many other types of cells. Energy is released and carbon dioxide and water are produced.
5. The energy released by respiration is used for the life processes of most living organisms, including plants.
6. Photosynthesis and respiration are almost the reverse of each other. The end products of photosynthesis are the raw materials needed for aerobic respiration. The end products of aerobic respiration are the raw materials needed for photosynthesis.

Section 2 Plant Responses

1. Plants respond positively and negatively to stimuli. The response may be a movement, a change in growth, or the beginning of some process such as flowering.
2. A stimulus from outside the plant is called a tropism. Outside stimuli include light, gravity, and touch.
3. The length of darkness each day can affect flowering times of plants.
4. Plant hormones cause responses in plants. Some hormones cause plants to exhibit tropisms. Other hormones cause changes in plant growth rates.

Visualizing Main Ideas

Copy and complete the following concept map on photosynthesis and respiration.



(l)Norm Thomas/Photo Researchers, (r)S.R. Maglione/Photo Researchers

chapter 5 Review

Using Vocabulary

auxin p. 136
chlorophyll p. 126
day-neutral plant p. 138
long-day plant p. 138
photoperiodism p. 138
photosynthesis p. 127
respiration p. 129
short-day plant p. 138
stomata p. 125
tropism p. 134

Fill in the blanks with the correct vocabulary word(s) from the list above.

1. ________ is a hormone that causes plant stems and leaves to exhibit positive phototropism.
2. ________ is a light-dependent process conducted by green plants but not by animals.
3. ________ is required for photosynthesis.
4. A poinsettia, often seen flowering during December holidays, is a(n) ________.
5. In most living things, energy is released from food by ________.
6. Spinach requires only ten hours of darkness to flower, which makes it a(n) ________.
7. A(n) ________ can cause a plant to bend toward light.
8. Plants usually take in carbon dioxide through ________.
9. ________ controls a plant's response to day length.
10. Plants that flower without regard to day length are ________.

Checking Concepts

Choose the word or phrase that best answers the question.

11. What raw material needed by plants enters through open stomata?
    A) sugar **C)** carbon dioxide
    B) chlorophyll **D)** cellulose

12. What is a function of stomata?
    A) photosynthesis
    B) to guard the interior cells
    C) to allow sugar to escape
    D) to permit the release of oxygen

13. What plant process produces water, carbon dioxide, and energy?
    A) cell division **C)** growth
    B) photosynthesis **D)** respiration

14. What are the products of photosynthesis?
    A) glucose and oxygen
    B) carbon dioxide and water
    C) chlorophyll and glucose
    D) carbon dioxide and oxygen

15. What are plant substances that affect plant growth called?
    A) tropisms **C)** germination
    B) glucose **D)** hormones

16. Leaves change colors because what substance breaks down?
    A) hormone **C)** chlorophyll
    B) carotenoid **D)** cytoplasm

17. Which of these is a product of respiration?
    A) CO_2 **C)** C_2H_4
    B) O_2 **D)** H_2

Use the photo below to answer question 18.

18. What stimulus is this plant responding to?
    A) light **C)** touch
    B) gravity **D)** water

Runk/Schoenberger from Grant Heilman

Science Online bookb.msscience.com/vocabulary_puzzlemaker
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Thinking Critically

19. Predict You buy pears at the store that are not completely ripe. What could you do to help them ripen more rapidly?

20. Name each tropism and state whether it is positive or negative.

a. Stem grows up.
b. Roots grow down.
c. Plant grows toward light.
d. A vine grows around a pole.

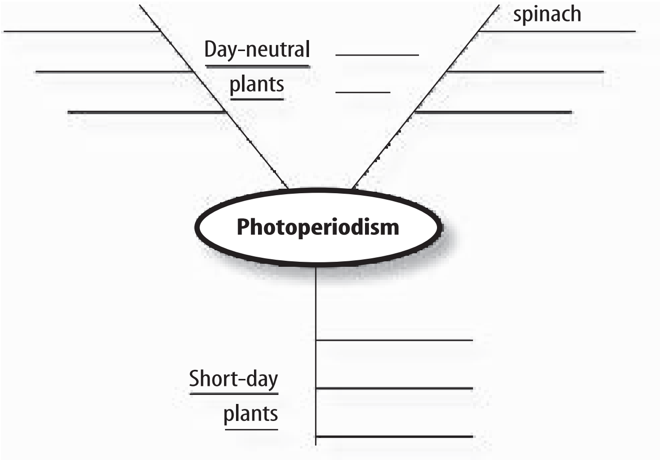
21. Infer Scientists who study sedimentary rocks and fossils suggest that oxygen was not in Earth's atmosphere until plantlike, one-celled organisms appeared. Why?

22. Explain why apple trees bloom in the spring but not in the summer.

23. Discuss why day-neutral and long-day plants grow best in countries near the equator.

24. Form a hypothesis about when guard cells open and close in desert plants.

25. Concept Map Copy and complete the following concept map about photoperiodism using the following information: flower year-round—*corn, dandelion, tomato*; flower in the spring, fall, or winter—*chrysanthemum, rice, poinsettia*; flower in summer—*spinach, lettuce, petunia.*



26. Compare and contrast the action of auxin and the action of ethylene on a plant.

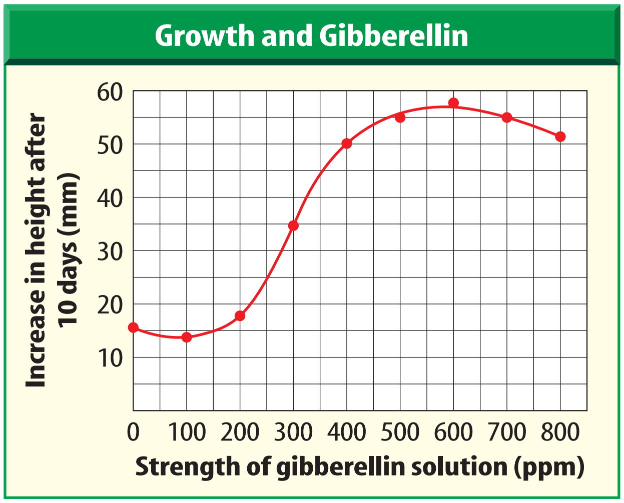
Performance Activities

27. Coloring Book Create a coloring book of day-neutral plants, long-day plants, and short-day plants. Use pictures from magazines and seed catalogs to get your ideas. Label the drawings with the plant's name and how it responds to darkness. Let a younger student color the flowers in your book.

Applying Math

28. Stomata A houseplant leaf has 1,573 stomata. During daylight hours, when the plant is well watered, about 90 percent of the stomata were open. During daylight hours when the soil was dry, about 25 percent of the stomata remained open. How many stomata were open (a) when the soil was wet and (b) when it was dry?

Use the graph below to answer question 29.



29. Gibberellins The graph above shows the results of applying different amounts of gibberellin to the roots of bean plants. What effect did a 100-ppm solution of gibberellin have on bean plant growth? Which gibberellin solution resulted in the tallest plants?

chapter 5 Standardized Test Practice

Part 1 Multiple Choice

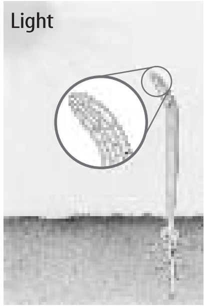
Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

1. Which statement correctly describes the leaf epidermis?
A. This is an inner cell layer of the leaf.
B. This layer is nearly transparent.
C. Food is made in this layer.
D. Sunlight cannot penetrate this layer.

2. What happens when a plant is losing too much water?
A. stomata close
B. guard cells swell
C. stomata open
D. respiration increases

3. Which statement is TRUE?
A. Changes in length of daylight and darkness have no effect on plant growth.
B. Plants that need less than 10 to 12 hours of darkness to flower are called short-day plants.
C. Plants that need 12 or more hours of darkness to flower are called short-day plants.
D. Very few plants rely on a specific length of darkness to flower.

Use the illustration below to answer question 4.



4. The plant above is showing a growth response that is controlled by
A. auxin. **C.** abscisic acid.
B. gravity. **D.** length of darkness.

Use the illustration below to answer questions 5 and 6.

5. What type of response is displayed by this plant?
A. negative phototropism
B. positive gravitropism
C. positive phototropism
D. negative gravitropism

6. What plant hormone is responsible for the response shown here?
A. abscisic acid **C.** a gibberellin
B. auxin **D.** a cytokinin

7. In which plant cell structure does respiration take place?
A. nucleus **C.** vacuole
B. mitochondrion **D.** cell wall

8. Which of these is NOT produced through aerobic respiration?
A. glucose **C.** water
B. energy **D.** carbon dioxide

9. Which plant hormone prevents the development of buds during the winter?
A. abscisic acid **C.** gibberellin
B. auxin **D.** cytokinin

10. What chemical absorbs light energy which plants use in photosynthesis?
A. oxygen **C.** chlorophyll
B. hydrogen **D.** glucose

Matt Meadows

Part 2 Short Response/Grid In

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

Use the illustration below to answer questions 11 and 12.

$$6CO_2 + 6\,H_2O + \text{light energy} \xrightarrow{\text{chlorophyll}} C_6H_{12}O_6 + 6O_2$$

11. Identify this process. How would this process change if the amount of available water was limited?

12. Based on this equation, what is the main food source for plant cells? How do animals use this food source?

13. Why is respiration necessary for plants? Describe some plant processes which require energy.

14. What advantage do growers gain by picking and shipping unripe fruit? What role does ethylene play in this commercial process?

15. Identify specific stimuli to which plants respond in the natural environment.

16. Many people who save poinsettia plants from Christmas cannot get them to flower the following Christmas. Why?

17. What effect have commercial greenhouses had on the availability of long-day and short-day plants year-round?

18. Where are stomata found on the leaf? What function do these structures perform?

19. Describe the relationship between chlorophyll and the color of leaves in spring and summer.

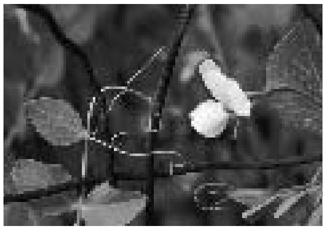
Part 3 Open Ended

Record your answers on a sheet of paper.

20. Cellulose is an important component of plants. Describe its relationship to glucose. Identify cell and plant structures which contain significant amounts of cellulose.

21. Organisms which make their own food generate most of the oxygen in Earth's atmosphere. Trace the path of this element from a component of water in the soil to a gas in the air.

Use the illustration below to answer questions 22 and 23.



22. Explain how the tropism shown by this plant could help a gardener incorporate a larger number of plants into a small vegetable garden plot.

23. What advantages might thigmotropism, the response shown in this picture, provide for some plants?

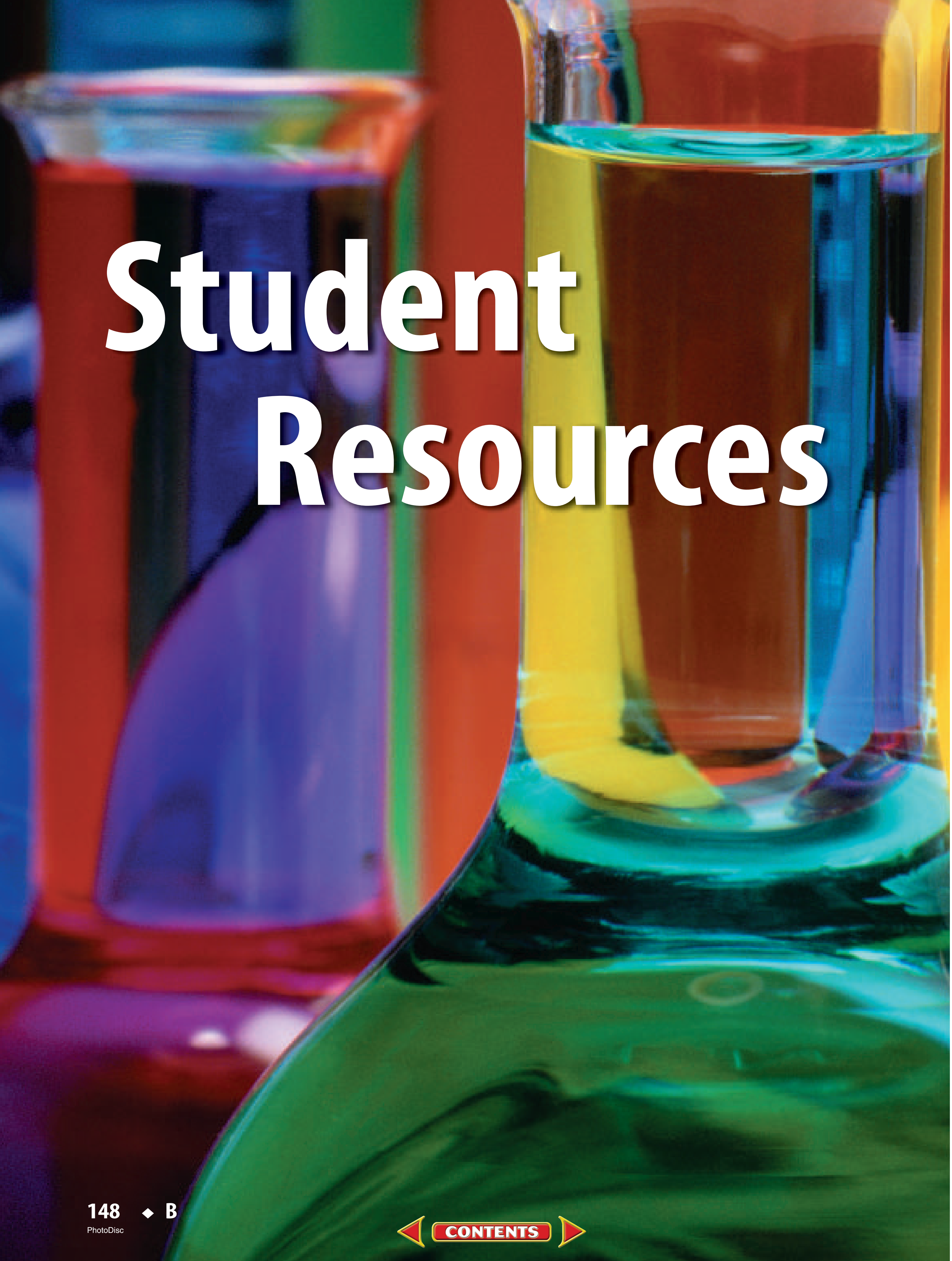
24. The destruction of large areas of rain forest concerns scientists on many levels. Describe the relationship between environmental conditions for plant growth in rainforest regions, their relative rate of photosynthesis, and the amount of oxygen this process adds to the atmosphere.

Test-Taking Tip

Pace Yourself If you are taking a timed test, keep track of time during the test. If you find that you're spending too much time on a multiple-choice question, mark your best guess and move on.

Scott Camazine/Photo Researchers

Student Resources



PhotoDisc

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Scientific Methods

Scientists use an orderly approach called the scientific method to solve problems. This includes organizing and recording data so others can understand them. Scientists use many variations in this method when they solve problems.

Identify a Question

The first step in a scientific investigation or experiment is to identify a question to be answered or a problem to be solved. For example, you might ask which gasoline is the most efficient.

Gather and Organize Information

After you have identified your question, begin gathering and organizing information. There are many ways to gather information, such as researching in a library, interviewing those knowledgeable about the subject, testing and working in the laboratory and field. Fieldwork is investigations and observations done outside of a laboratory.

Researching Information Before moving in a new direction, it is important to gather the information that already is known about the subject. Start by asking yourself questions to determine exactly what you need to know. Then you will look for the information in various reference sources, like the student is doing in **Figure 1.** Some sources may include textbooks, encyclopedias, government documents, professional journals, science magazines, and the Internet. Always list the sources of your information.

Figure 1 The Internet can be a valuable research tool.

Evaluate Sources of Information Not all sources of information are reliable. You should evaluate all of your sources of information, and use only those you know to be dependable. For example, if you are researching ways to make homes more energy efficient, a site written by the U.S. Department of Energy would be more reliable than a site written by a company that is trying to sell a new type of weatherproofing material. Also, remember that research always is changing. Consult the most current resources available to you. For example, a 1985 resource about saving energy would not reflect the most recent findings.

Sometimes scientists use data that they did not collect themselves, or conclusions drawn by other researchers. This data must be evaluated carefully. Ask questions about how the data were obtained, if the investigation was carried out properly, and if it has been duplicated exactly with the same results. Would you reach the same conclusion from the data? Only when you have confidence in the data can you believe it is true and feel comfortable using it.

Tom Pantages

Interpret Scientific Illustrations As you research a topic in science, you will see drawings, diagrams, and photographs to help you understand what you read. Some illustrations are included to help you understand an idea that you can't see easily by yourself, like the tiny particles in an atom in **Figure 2.** A drawing helps many people to remember details more easily and provides examples that clarify difficult concepts or give additional information about the topic you are studying. Most illustrations have labels or a caption to identify or to provide more information.

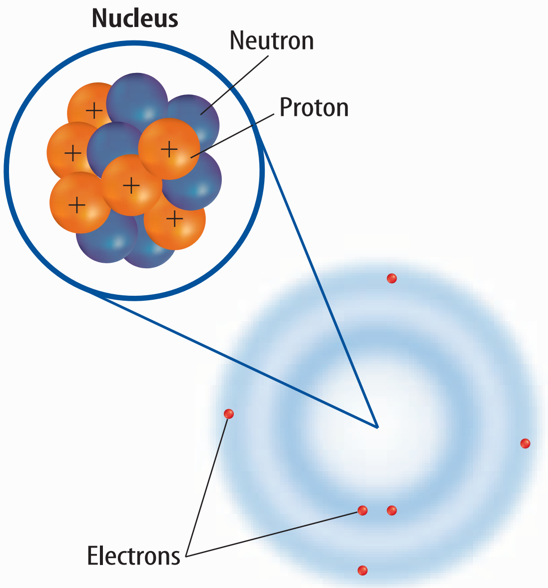


Figure 2 This drawing shows an atom of carbon with its six protons, six neutrons, and six electrons.

Concept Maps One way to organize data is to draw a diagram that shows relationships among ideas (or concepts). A concept map can help make the meanings of ideas and terms more clear, and help you understand and remember what you are studying. Concept maps are useful for breaking large concepts down into smaller parts, making learning easier.

Network Tree A type of concept map that not only shows a relationship, but how the concepts are related is a network tree, shown in **Figure 3.** In a network tree, the words are written in the ovals, while the description of the type of relationship is written across the connecting lines.

When constructing a network tree, write down the topic and all major topics on separate pieces of paper or notecards. Then arrange them in order from general to specific. Branch the related concepts from the major concept and describe the relationship on the connecting line. Continue to more specific concepts until finished.

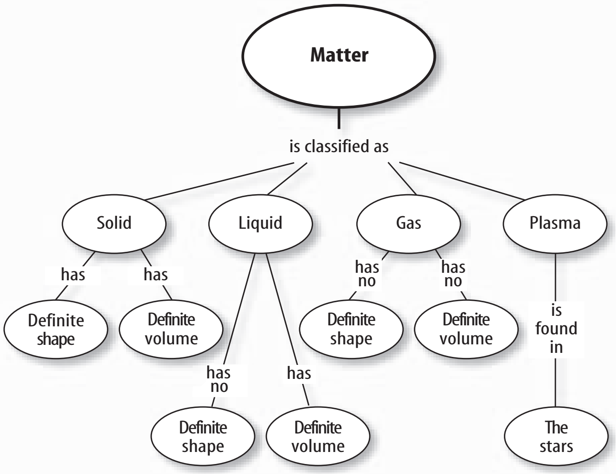


Figure 3 A network tree shows how concepts or objects are related.

Events Chain Another type of concept map is an events chain. Sometimes called a flow chart, it models the order or sequence of items. An events chain can be used to describe a sequence of events, the steps in a procedure, or the stages of a process.

When making an events chain, first find the one event that starts the chain. This event is called the initiating event. Then, find the next event and continue until the outcome is reached, as shown in **Figure 4.**

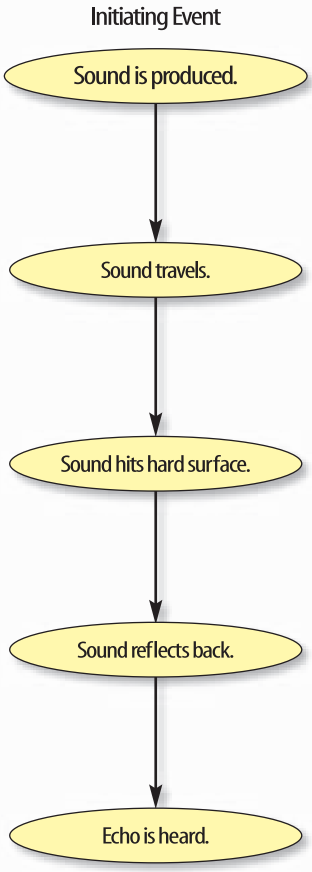


Figure 4 Events-chain concept maps show the order of steps in a process or event. This concept map shows how a sound makes an echo.

Cycle Map A specific type of events chain is a cycle map. It is used when the series of events do not produce a final outcome, but instead relate back to the beginning event, such as in **Figure 5.** Therefore, the cycle repeats itself.

To make a cycle map, first decide what event is the beginning event. This is also called the initiating event. Then list the next events in the order that they occur, with the last event relating back to the initiating event. Words can be written between the events that describe what happens from one event to the next. The number of events in a cycle map can vary, but usually contain three or more events.

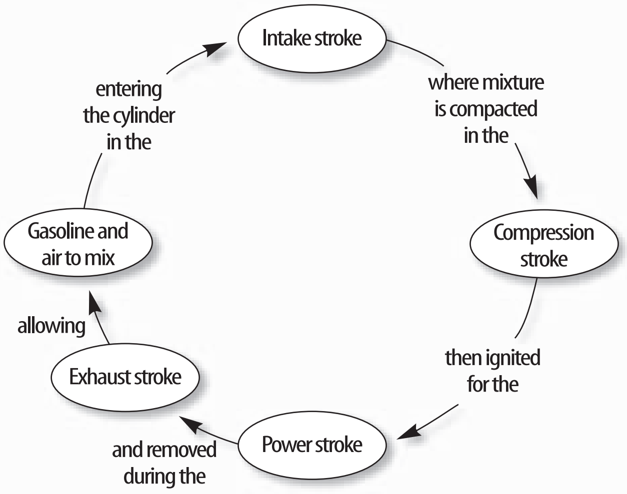


Figure 5 A cycle map shows events that occur in a cycle.

Spider Map A type of concept map that you can use for brainstorming is the spider map. When you have a central idea, you might find that you have a jumble of ideas that relate to it but are not necessarily clearly related to each other. The spider map on sound in **Figure 6** shows that if you write these ideas outside the main concept, then you can begin to separate and group unrelated terms so they become more useful.

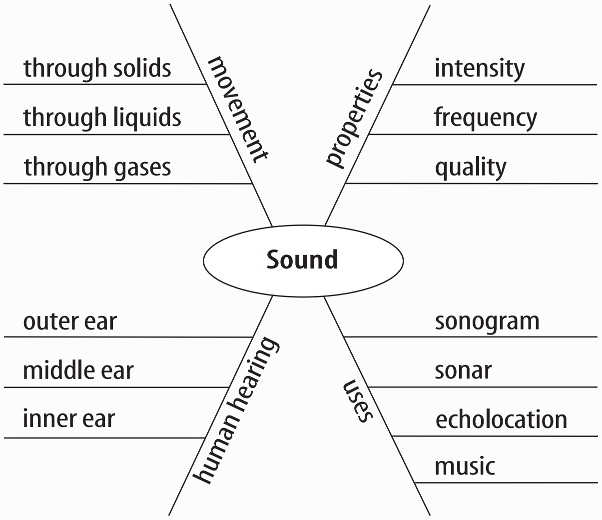


Figure 6 A spider map allows you to list ideas that relate to a central topic but not necessarily to one another.

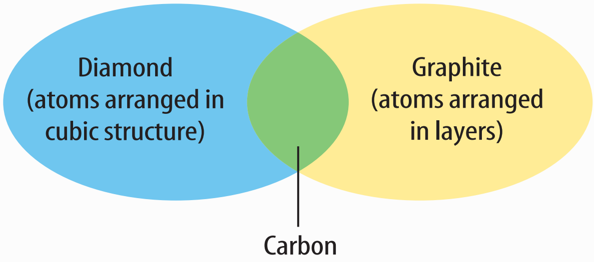


Figure 7 This Venn diagram compares and contrasts two substances made from carbon.

Venn Diagram To illustrate how two subjects compare and contrast you can use a Venn diagram. You can see the characteristics that the subjects have in common and those that they do not, shown in **Figure 7.**

To create a Venn diagram, draw two overlapping ovals that that are big enough to write in. List the characteristics unique to one subject in one oval, and the characteristics of the other subject in the other oval. The characteristics in common are listed in the overlapping section.

Make and Use Tables One way to organize information so it is easier to understand is to use a table. Tables can contain numbers, words, or both.

To make a table, list the items to be compared in the first column and the characteristics to be compared in the first row. The title should clearly indicate the content of the table, and the column or row heads should be clear. Notice that in **Table 1** the units are included.

Table 1 Recyclables Collected During Week

Day of Week	Paper (kg)	Aluminum (kg)	Glass (kg)
Monday	5.0	4.0	12.0
Wednesday	4.0	1.0	10.0
Friday	2.5	2.0	10.0

Make a Model One way to help you better understand the parts of a structure, the way a process works, or to show things too large or small for viewing is to make a model. For example, an atomic model made of a plastic-ball nucleus and pipe-cleaner electron shells can help you visualize how the parts of an atom relate to each other. Other types of models can by devised on a computer or represented by equations.

Form a Hypothesis

A possible explanation based on previous knowledge and observations is called a hypothesis. After researching gasoline types and recalling previous experiences in your family's car you form a hypothesis—our car runs more efficiently because we use premium gasoline. To be valid, a hypothesis has to be something you can test by using an investigation.

Predict When you apply a hypothesis to a specific situation, you predict something about that situation. A prediction makes a statement in advance, based on prior observation, experience, or scientific reasoning. People use predictions to make everyday decisions. Scientists test predictions by performing investigations. Based on previous observations and experiences, you might form a prediction that cars are more efficient with premium gasoline. The prediction can be tested in an investigation.

Design an Experiment A scientist needs to make many decisions before beginning an investigation. Some of these include: how to carry out the investigation, what steps to follow, how to record the data, and how the investigation will answer the question. It also is important to address any safety concerns.

Test the Hypothesis

Now that you have formed your hypothesis, you need to test it. Using an investigation, you will make observations and collect data, or information. This data might either support or not support your hypothesis. Scientists collect and organize data as numbers and descriptions.

Follow a Procedure In order to know what materials to use, as well as how and in what order to use them, you must follow a procedure. **Figure 8** shows a procedure you might follow to test your hypothesis.

Procedure

1. Use regular gasoline for two weeks.
2. Record the number of kilometers between fill-ups and the amount of gasoline used.
3. Switch to premium gasoline for two weeks.
4. Record the number of kilometers between fill-ups and the amount of gasoline used.

Figure 8 A procedure tells you what to do step by step.

Identify and Manipulate Variables and Controls In any experiment, it is important to keep everything the same except for the item you are testing. The one factor you change is called the independent variable. The change that results is the dependent variable. Make sure you have only one independent variable, to assure yourself of the cause of the changes you observe in the dependent variable. For example, in your gasoline experiment the type of fuel is the independent variable. The dependent variable is the efficiency.

Many experiments also have a control—an individual instance or experimental subject for which the independent variable is not changed. You can then compare the test results to the control results. To design a control you can have two cars of the same type. The control car uses regular gasoline for four weeks. After you are done with the test, you can compare the experimental results to the control results.

Collect Data

Whether you are carrying out an investigation or a short observational experiment, you will collect data, as shown in **Figure 9.** Scientists collect data as numbers and descriptions and organize it in specific ways.

Observe Scientists observe items and events, then record what they see. When they use only words to describe an observation, it is called qualitative data. Scientists' observations also can describe how much there is of something. These observations use numbers, as well as words, in the description and are called quantitative data. For example, if a sample of the element gold is described as being "shiny and very dense" the data are qualitative. Quantitative data on this sample of gold might include "a mass of 30 g and a density of 19.3 g/cm^3."

Figure 9 Collecting data is one way to gather information directly.

Michell D. Bridwell/PhotoEdit, Inc.

Figure 10 Record data neatly and clearly so it is easy to understand.

When you make observations you should examine the entire object or situation first, and then look carefully for details. It is important to record observations accurately and completely. Always record your notes immediately as you make them, so you do not miss details or make a mistake when recording results from memory. Never put unidentified observations on scraps of paper. Instead they should be recorded in a notebook, like the one in **Figure 10.** Write your data neatly so you can easily read it later. At each point in the experiment, record your observations and label them. That way, you will not have to determine what the figures mean when you look at your notes later. Set up any tables that you will need to use ahead of time, so you can record any observations right away. Remember to avoid bias when collecting data by not including personal thoughts when you record observations. Record only what you observe.

Estimate Scientific work also involves estimating. To estimate is to make a judgment about the size or the number of something without measuring or counting. This is important when the number or size of an object or population is too large or too difficult to accurately count or measure.

Sample Scientists may use a sample or a portion of the total number as a type of estimation. To sample is to take a small, representative portion of the objects or organisms of a population for research. By making careful observations or manipulating variables within that portion of the group, information is discovered and conclusions are drawn that might apply to the whole population. A poorly chosen sample can be unrepresentative of the whole. If you were trying to determine the rainfall in an area, it would not be best to take a rainfall sample from under a tree.

Measure You use measurements everyday. Scientists also take measurements when collecting data. When taking measurements, it is important to know how to use measuring tools properly. Accuracy also is important.

Length To measure length, the distance between two points, scientists use meters. Smaller measurements might be measured in centimeters or millimeters.

Length is measured using a metric ruler or meter stick. When using a metric ruler, line up the 0-cm mark with the end of the object being measured and read the number of the unit where the object ends. Look at the metric ruler shown in **Figure 11.** The centimeter lines are the long, numbered lines, and the shorter lines are millimeter lines. In this instance, the length would be 4.50 cm.

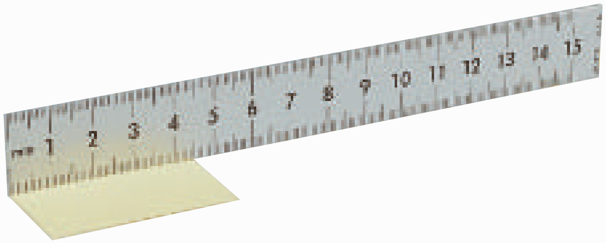


Figure 11 This metric ruler has centimeter and millimeter divisions.

(t)Mark Burnett, (b)Dominic Oldershaw

Mass The SI unit for mass is the kilogram (kg). Scientists can measure mass using units formed by adding metric prefixes to the unit gram (g), such as milligram (mg). To measure mass, you might use a triple-beam balance similar to the one shown in **Figure 12.** The balance has a pan on one side and a set of beams on the other side. Each beam has a rider that slides on the beam.

When using a triple-beam balance, place an object on the pan. Slide the largest rider along its beam until the pointer drops below zero. Then move it back one notch. Repeat the process for each rider proceeding from the larger to smaller until the pointer swings an equal distance above and below the zero point. Sum the masses on each beam to find the mass of the object. Move all riders back to zero when finished.

Instead of putting materials directly on the balance, scientists often take a tare of a container. A tare is the mass of a container into which objects or substances are placed for measuring their masses. To mass objects or substances, find the mass of a clean container. Remove the container from the pan, and place the object or substances in the container. Find the mass of the container with the materials in it. Subtract the mass of the empty container from the mass of the filled container to find the mass of the materials you are using.

Figure 12 A triple-beam balance is used to determine the mass of an object.

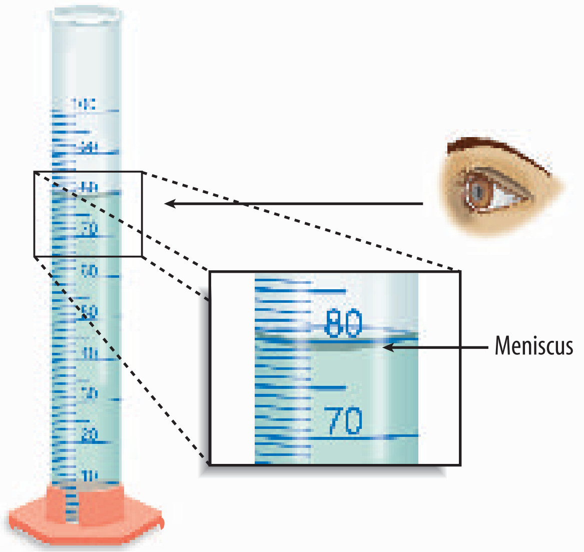


Figure 13 Graduated cylinders measure liquid volume.

Liquid Volume To measure liquids, the unit used is the liter. When a smaller unit is needed, scientists might use a milliliter. Because a milliliter takes up the volume of a cube measuring 1 cm on each side it also can be called a cubic centimeter ($cm^3 = cm \times cm \times cm$).

You can use beakers and graduated cylinders to measure liquid volume. A graduated cylinder, shown in **Figure 13,** is marked from bottom to top in milliliters. In lab, you might use a 10-mL graduated cylinder or a 100-mL graduated cylinder. When measuring liquids, notice that the liquid has a curved surface. Look at the surface at eye level, and measure the bottom of the curve. This is called the meniscus. The graduated cylinder in **Figure 13** contains 79.0 mL, or 79.0 cm^3, of a liquid.

Temperature Scientists often measure temperature using the Celsius scale. Pure water has a freezing point of 0°C and boiling point of 100°C. The unit of measurement is degrees Celsius. Two other scales often used are the Fahrenheit and Kelvin scales.

Figure 14 A thermometer measures the temperature of an object.

Scientists use a thermometer to measure temperature. Most thermometers in a laboratory are glass tubes with a bulb at the bottom end containing a liquid such as colored alcohol. The liquid rises or falls with a change in temperature. To read a glass thermometer like the thermometer in **Figure 14,** rotate it slowly until a red line appears. Read the temperature where the red line ends.

Form Operational Definitions An operational definition defines an object by how it functions, works, or behaves. For example, when you are playing hide and seek and a tree is home base, you have created an operational definition for a tree.

Objects can have more than one operational definition. For example, a ruler can be defined as a tool that measures the length of an object (how it is used). It can also be a tool with a series of marks used as a standard when measuring (how it works).

Analyze the Data

To determine the meaning of your observations and investigation results, you will need to look for patterns in the data. Then you must think critically to determine what the data mean. Scientists use several approaches when they analyze the data they have collected and recorded. Each approach is useful for identifying specific patterns.

Interpret Data The word *interpret* means "to explain the meaning of something." When analyzing data from an experiment, try to find out what the data show. Identify the control group and the test group to see whether or not changes in the independent variable have had an effect. Look for differences in the dependent variable between the control and test groups.

Classify Sorting objects or events into groups based on common features is called classifying. When classifying, first observe the objects or events to be classified. Then select one feature that is shared by some members in the group, but not by all. Place those members that share that feature in a subgroup. You can classify members into smaller and smaller subgroups based on characteristics. Remember that when you classify, you are grouping objects or events for a purpose. Keep your purpose in mind as you select the features to form groups and subgroups.

Compare and Contrast Observations can be analyzed by noting the similarities and differences between two more objects or events that you observe. When you look at objects or events to see how they are similar, you are comparing them. Contrasting is looking for differences in objects or events.

Recognize Cause and Effect A cause is a reason for an action or condition. The effect is that action or condition. When two events happen together, it is not necessarily true that one event caused the other. Scientists must design a controlled investigation to recognize the exact cause and effect.

Draw Conclusions

When scientists have analyzed the data they collected, they proceed to draw conclusions about the data. These conclusions are sometimes stated in words similar to the hypothesis that you formed earlier. They may confirm a hypothesis, or lead you to a new hypothesis.

Infer Scientists often make inferences based on their observations. An inference is an attempt to explain observations or to indicate a cause. An inference is not a fact, but a logical conclusion that needs further investigation. For example, you may infer that a fire has caused smoke. Until you investigate, however, you do not know for sure.

Apply When you draw a conclusion, you must apply those conclusions to determine whether the data supports the hypothesis. If your data do not support your hypothesis, it does not mean that the hypothesis is wrong. It means only that the result of the investigation did not support the hypothesis. Maybe the experiment needs to be redesigned, or some of the initial observations on which the hypothesis was based were incomplete or biased. Perhaps more observation or research is needed to refine your hypothesis. A successful investigation does not always come out the way you originally predicted.

Avoid Bias Sometimes a scientific investigation involves making judgments. When you make a judgment, you form an opinion. It is important to be honest and not to allow any expectations of results to bias your judgments. This is important throughout the entire investigation, from researching to collecting data to drawing conclusions.

Communicate

The communication of ideas is an important part of the work of scientists. A discovery that is not reported will not advance the scientific community's understanding or knowledge. Communication among scientists also is important as a way of improving their investigations.

Scientists communicate in many ways, from writing articles in journals and magazines that explain their investigations and experiments, to announcing important discoveries on television and radio. Scientists also share ideas with colleagues on the Internet or present them as lectures, like the student is doing in **Figure 15.**

Figure 15 A student communicates to his peers about his investigation.

Aaron Haupt

SAFETY SYMBOLS	HAZARD	EXAMPLES	PRECAUTION	REMEDY
DISPOSAL	Special disposal procedures need to be followed.	certain chemicals, living organisms	Do not dispose of these materials in the sink or trash can.	Dispose of wastes as directed by your teacher.
BIOLOGICAL	Organisms or other biological materials that might be harmful to humans	bacteria, fungi, blood, unpreserved tissues, plant materials	Avoid skin contact with these materials. Wear mask or gloves.	Notify your teacher if you suspect contact with material. Wash hands thoroughly.
EXTREME TEMPERATURE	Objects that can burn skin by being too cold or too hot	boiling liquids, hot plates, dry ice, liquid nitrogen	Use proper protection when handling.	Go to your teacher for first aid.
SHARP OBJECT	Use of tools or glassware that can easily puncture or slice skin	razor blades, pins, scalpels, pointed tools, dissecting probes, broken glass	Practice common-sense behavior and follow guidelines for use of the tool.	Go to your teacher for first aid.
FUME	Possible danger to respiratory tract from fumes	ammonia, acetone, nail polish remover, heated sulfur, moth balls	Make sure there is good ventilation. Never smell fumes directly. Wear a mask.	Leave foul area and notify your teacher immediately.
ELECTRICAL	Possible danger from electrical shock or burn	improper grounding, liquid spills, short circuits, exposed wires	Double-check setup with teacher. Check condition of wires and apparatus.	Do not attempt to fix electrical problems. Notify your teacher immediately.
IRRITANT	Substances that can irritate the skin or mucous membranes of the respiratory tract	pollen, moth balls, steel wool, fiberglass, potassium permanganate	Wear dust mask and gloves. Practice extra care when handling these materials.	Go to your teacher for first aid.
CHEMICAL	Chemicals can react with and destroy tissue and other materials	bleaches such as hydrogen peroxide; acids such as sulfuric acid, hydrochloric acid; bases such as ammonia, sodium hydroxide	Wear goggles, gloves, and an apron.	Immediately flush the affected area with water and notify your teacher.
TOXIC	Substance may be poisonous if touched, inhaled, or swallowed.	mercury, many metal compounds, iodine, poinsettia plant parts	Follow your teacher's instructions.	Always wash hands thoroughly after use. Go to your teacher for first aid.
FLAMMABLE	Flammable chemicals may be ignited by open flame, spark, or exposed heat.	alcohol, kerosene, potassium permanganate	Avoid open flames and heat when using flammable chemicals.	Notify your teacher immediately. Use fire safety equipment if applicable.
OPEN FLAME	Open flame in use, may cause fire.	hair, clothing, paper, synthetic materials	Tie back hair and loose clothing. Follow teacher's instruction on lighting and extinguishing flames.	Notify your teacher immediately. Use fire safety equipment if applicable.

Eye Safety
Proper eye protection should be worn at all times by anyone performing or observing science activities.

Clothing Protection
This symbol appears when substances could stain or burn clothing.

Animal Safety
This symbol appears when safety of animals and students must be ensured.

Handwashing
After the lab, wash hands with soap and water before removing goggles.

Safety in the Science Laboratory

The science laboratory is a safe place to work if you follow standard safety procedures. Being responsible for your own safety helps to make the entire laboratory a safer place for everyone. When performing any lab, read and apply the caution statements and safety symbol listed at the beginning of the lab.

General Safety Rules

1. Obtain your teacher's permission to begin all investigations and use laboratory equipment.
2. Study the procedure. Ask your teacher any questions. Be sure you understand safety symbols shown on the page.
3. Notify your teacher about allergies or other health conditions which can affect your participation in a lab.
4. Learn and follow use and safety procedures for your equipment. If unsure, ask your teacher.

5. Never eat, drink, chew gum, apply cosmetics, or do any personal grooming in the lab. Never use lab glassware as food or drink containers. Keep your hands away from your face and mouth.
6. Know the location and proper use of the safety shower, eye wash, fire blanket, and fire alarm.

Prevent Accidents

1. Use the safety equipment provided to you. Goggles and a safety apron should be worn during investigations.
2. Do NOT use hair spray, mousse, or other flammable hair products. Tie back long hair and tie down loose clothing.
3. Do NOT wear sandals or other open-toed shoes in the lab.
4. Remove jewelry on hands and wrists. Loose jewelry, such as chains and long necklaces, should be removed to prevent them from getting caught in equipment.
5. Do not taste any substances or draw any material into a tube with your mouth.
6. Proper behavior is expected in the lab. Practical jokes and fooling around can lead to accidents and injury.
7. Keep your work area uncluttered.

Laboratory Work

1. Collect and carry all equipment and materials to your work area before beginning a lab.
2. Remain in your own work area unless given permission by your teacher to leave it.

KS Studios

3. Always slant test tubes away from yourself and others when heating them, adding substances to them, or rinsing them.
4. If instructed to smell a substance in a container, hold the container a short distance away and fan vapors towards your nose.
5. Do NOT substitute other chemicals/substances for those in the materials list unless instructed to do so by your teacher.
6. Do NOT take any materials or chemicals outside of the laboratory.
7. Stay out of storage areas unless instructed to be there and supervised by your teacher.

Laboratory Cleanup

1. Turn off all burners, water, and gas, and disconnect all electrical devices.
2. Clean all pieces of equipment and return all materials to their proper places.
3. Dispose of chemicals and other materials as directed by your teacher. Place broken glass and solid substances in the proper containers. Never discard materials in the sink.
4. Clean your work area.
5. Wash your hands with soap and water thoroughly BEFORE removing your goggles.

Emergencies

1. Report any fire, electrical shock, glassware breakage, spill, or injury, no matter how small, to your teacher immediately. Follow his or her instructions.
2. If your clothing should catch fire, STOP, DROP, and ROLL. If possible, smother it with the fire blanket or get under a safety shower. NEVER RUN.
3. If a fire should occur, turn off all gas and leave the room according to established procedures.
4. In most instances, your teacher will clean up spills. Do NOT attempt to clean up spills unless you are given permission and instructions to do so.
5. If chemicals come into contact with your eyes or skin, notify your teacher immediately. Use the eyewash or flush your skin or eyes with large quantities of water.
6. The fire extinguisher and first-aid kit should only be used by your teacher unless it is an extreme emergency and you have been given permission.
7. If someone is injured or becomes ill, only a professional medical provider or someone certified in first aid should perform first-aid procedures.

Matt Meadows

EXTRA Try at Home Labs

From Your Kitchen, Junk Drawer, or Yard

1 Beating Bacteria

Real-World Question

How do we protect our foods from bacteria?

Possible Materials

- heavy cream or whole milk
- plastic drinking glasses (3)
- refrigerator

Procedure

1. Pour milk into three identical glasses until each glass is three-quarters full.
2. Place one glass in the back of your refrigerator where it will not be disturbed.
3. Place a second glass in a dark, cool place such as inside a kitchen cabinet.
4. Place the third glass on a windowsill in direct sunlight.
5. Observe the milk in each glass every day for several days. In your Science Journal, write down your observations about what is happening to the milk each day.

Conclude and Apply

1. Describe what happened to the milk in each of the glasses.
2. Infer what caused the change in the milk on the windowsill.
3. Infer how a refrigerator affects bacteria in food.

2 Fungus Foods

Real-World Question

How do we protect our foods from mold?

Possible Materials

- unopened jars of baby food or some other type of food such as spaghetti sauce or salsa (4)
- plate
- spoon
- magnifying lens

Procedure

1. Open one of the jars of food and spread the contents out over a plate.
2. Place the plate in a cool place away from direct sunlight where it will not be disturbed for several days.
3. Open a second jar of food and set it next to the plate without the lid on.
4. Break the seal of the third jar of food and set it next to the second jar with the lid on.
5. Do not open the fourth jar but place it next to the other two jars.
6. Observe the food in the jars and on the plate each day for the next several days. Record your observations in your Science Journal.

Conclude and Apply

1. Describe what happened to the food in each container.
2. Explain how food companies use packaging to protect the foods you buy from fungi such as mold.

Adult supervision required for all labs.

(t)Matt Meadows, (b)Science VU/Visuals Unlimited

3 Prickly Plants

Real-World Question

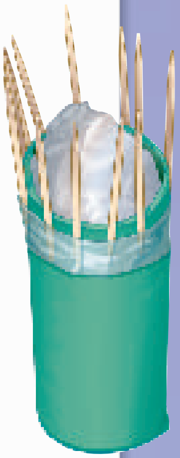
Why does a cactus have spines?

Possible Materials

- toilet paper roll or paper towel roll (cut in half)
- transparent tape
- toothpicks (15)
- metric ruler
- oven mitt
- plastic bag or tissue paper

Procedure

1. Stuff the plastic bag or tissue paper into the toilet paper roll so that the bag or tissue is just inside the roll's rim.
2. Stand the roll on a table and hold it firmly with one hand. Place the oven mitt on your other hand and try to take the bag out of the roll.
3. If needed, place the bag back into the roll.
4. Securely tape toothpicks around the lip of the roll about 1 cm apart. About 4 cm of each toothpick should stick up above the rim.
5. Hold the roll on the table, put the oven mitt on, and try to take the bag out of the roll without breaking the toothpicks.



Conclude and Apply

1. Compare how easy it was to remove the plastic bag from the toilet paper roll with and without the toothpicks protecting it.
2. Describe the role of a cactus' spines.

4 Feed the Birds

Real-World Question

How can you attract hummingbirds to your yard?

Possible Materials

- plastic water bottle (20 oz) with bent tube or straw (10 cm length)
- sugar
- water
- pot
- wooden spoon
- red plastic flowers
- red tape or red plastic wrap
- narrow net bag
- strong string or wire

Procedure

1. Wrap red tape or fasten red plastic wrap around the bottle. Fasten red flowers to the bottle.
2. Boil 800 mL of water and gradually stir in 200 mL of sugar until all the sugar is dissolved. Let the solution cool and fill the bottle with the solution.
3. Hang the bottle upside down in the net bag and hang the feeder by a string in a shady location. Hang it above bright red or pink flowers if possible.
4. Observe your feeder daily and watch for hummingbirds.
5. Clean your bottle and refill it with fresh sugar solution every three days.

Conclude and Apply

1. Explain why hummingbirds, bees, bats, and other animals are important to plant reproduction.
2. Infer why flowers are usually brightly colored.

Adult supervision required for all labs.

Sid & Shirley Rucker/DRK Photo

5 Breathing Plants

Real-World Question

How do plants breathe?

Possible Materials

- houseplant
- petroleum jelly
- paper towel
- soap
- water

Procedure

1. Scoop some petroleum jelly out of the jar with your fingertips and coat the top of three or four leaves of the houseplant. Cover the entire top surface of the leaves only.
2. Coat the bottom of three or four different leaves with a layer of jelly.
3. Choose two or three stems not connected to the leaves you have covered with jelly. Coat these stems from top to bottom with a layer of jelly. Cover the entire stems but not their leaves.
4. Wash your hands with soap and water.
5. Observe the houseplant for three days.

Conclude and Apply

1. Describe what happened to the leaves and stems covered with jelly.
2. Infer how plants breathe.

Adult supervision required for all labs.

Aaron Haupt

Computer Skills

People who study science rely on computers, like the one in **Figure 16,** to record and store data and to analyze results from investigations. Whether you work in a laboratory or just need to write a lab report with tables, good computer skills are a necessity.

Using the computer comes with responsibility. Issues of ownership, security, and privacy can arise. Remember, if you did not author the information you are using, you must provide a source for your information. Also, anything on a computer can be accessed by others. Do not put anything on the computer that you would not want everyone to know. To add more security to your work, use a password.

Use a Word Processing Program

A computer program that allows you to type your information, change it as many times as you need to, and then print it out is called a word processing program. Word processing programs also can be used to make tables.

Figure 16 A computer will make reports neater and more professional looking.

Learn the Skill To start your word processing program, a blank document, sometimes called "Document 1," appears on the screen. To begin, start typing. To create a new document, click the *New* button on the standard tool bar. These tips will help you format the document.

- The program will automatically move to the next line; press *Enter* if you wish to start a new paragraph.
- Symbols, called non-printing characters, can be hidden by clicking the *Show/Hide* button on your toolbar.
- To insert text, move the cursor to the point where you want the insertion to go, click on the mouse once, and type the text.
- To move several lines of text, select the text and click the *Cut* button on your toolbar. Then position your cursor in the location that you want to move the cut text and click *Paste*. If you move to the wrong place, click *Undo*.
- The spell check feature does not catch words that are misspelled to look like other words, like "cold" instead of "gold." Always reread your document to catch all spelling mistakes.
- To learn about other word processing methods, read the user's manual or click on the *Help* button.
- You can integrate databases, graphics, and spreadsheets into documents by copying from another program and pasting it into your document, or by using desktop publishing (DTP). DTP software allows you to put text and graphics together to finish your document with a professional look. This software varies in how it is used and its capabilities.

Technology Skill Handbook

Amanita Pictures

Use a Database

A collection of facts stored in a computer and sorted into different fields is called a database. A database can be reorganized in any way that suits your needs.

Learn the Skill A computer program that allows you to create your own database is a database management system (DBMS). It allows you to add, delete, or change information. Take time to get to know the features of your database software.

- Determine what facts you would like to include and research to collect your information.
- Determine how you want to organize the information.
- Follow the instructions for your particular DBMS to set up fields. Then enter each item of data in the appropriate field.
- Follow the instructions to sort the information in order of importance.
- Evaluate the information in your database, and add, delete, or change as necessary.

Use the Internet

The Internet is a global network of computers where information is stored and shared. To use the Internet, like the students in **Figure 17,** you need a modem to connect your computer to a phone line and an Internet Service Provider account.

Learn the Skill To access internet sites and information, use a "Web browser," which lets you view and explore pages on the World Wide Web. Each page is its own site, and each site has its own address, called a URL. Once you have found a Web browser, follow these steps for a search (this also is how you search a database).

Figure 17 The Internet allows you to search a global network for a variety of information.

- Be as specific as possible. If you know you want to research "gold," don't type in "elements." Keep narrowing your search until you find what you want.
- Web sites that end in *.com* are commercial Web sites; *.org*, *.edu*, and *.gov* are non-profit, educational, or government Web sites.
- Electronic encyclopedias, almanacs, indexes, and catalogs will help locate and select relevant information.
- Develop a "home page" with relative ease. When developing a Web site, NEVER post pictures or disclose personal information such as location, names, or phone numbers. Your school or community usually can host your Web site. A basic understanding of HTML (hypertext mark-up language), the language of Web sites, is necessary. Software that creates HTML code is called authoring software, and can be downloaded free from many Web sites. This software allows text and pictures to be arranged as the software is writing the HTML code.

Bob Daemmrich

Use a Spreadsheet

A spreadsheet, shown in **Figure 18,** can perform mathematical functions with any data arranged in columns and rows. By entering a simple equation into a cell, the program can perform operations in specific cells, rows, or columns.

Learn the Skill Each column (vertical) is assigned a letter, and each row (horizontal) is assigned a number. Each point where a row and column intersect is called a cell, and is labeled according to where it is located—Column A, Row 1 (A1).

- Decide how to organize the data, and enter it in the correct row or column.
- Spreadsheets can use standard formulas or formulas can be customized to calculate cells.
- To make a change, click on a cell to make it activate, and enter the edited data or formula.
- Spreadsheets also can display your results in graphs. Choose the style of graph that best represents the data.

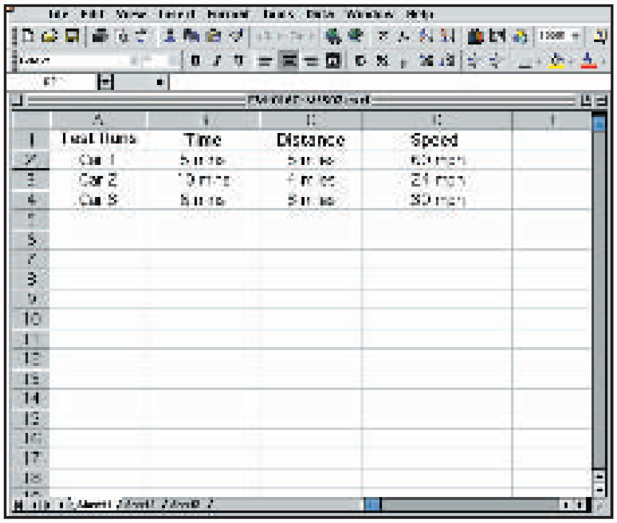


Figure 18 A spreadsheet allows you to perform mathematical operations on your data.

Use Graphics Software

Adding pictures, called graphics, to your documents is one way to make your documents more meaningful and exciting. This software adds, edits, and even constructs graphics. There is a variety of graphics software programs. The tools used for drawing can be a mouse, keyboard, or other specialized devices. Some graphics programs are simple. Others are complicated, called computer-aided design (CAD) software.

Learn the Skill It is important to have an understanding of the graphics software being used before starting. The better the software is understood, the better the results. The graphics can be placed in a word-processing document.

- Clip art can be found on a variety of internet sites, and on CDs. These images can be copied and pasted into your document.
- When beginning, try editing existing drawings, then work up to creating drawings.
- The images are made of tiny rectangles of color called pixels. Each pixel can be altered.
- Digital photography is another way to add images. The photographs in the memory of a digital camera can be downloaded into a computer, then edited and added to the document.
- Graphics software also can allow animation. The software allows drawings to have the appearance of movement by connecting basic drawings automatically. This is called in-betweening, or tweening.
- Remember to save often.

Technology Skill Handbook

Presentation Skills

Develop Multimedia Presentations

Most presentations are more dynamic if they include diagrams, photographs, videos, or sound recordings, like the one shown in **Figure 19.** A multimedia presentation involves using stereos, overhead projectors, televisions, computers, and more.

Learn the Skill Decide the main points of your presentation, and what types of media would best illustrate those points.

- Make sure you know how to use the equipment you are working with.
- Practice the presentation using the equipment several times.
- Enlist the help of a classmate to push play or turn lights out for you. Be sure to practice your presentation with him or her.
- If possible, set up all of the equipment ahead of time, and make sure everything is working properly.

Figure 19 These students are engaging the audience using a variety of tools.

Computer Presentations

There are many different interactive computer programs that you can use to enhance your presentation. Most computers have a compact disc (CD) drive that can play both CDs and digital video discs (DVDs). Also, there is hardware to connect a regular CD, DVD, or VCR. These tools will enhance your presentation.

Another method of using the computer to aid in your presentation is to develop a slide show using a computer program. This can allow movement of visuals at the presenter's pace, and can allow for visuals to build on one another.

Learn the Skill In order to create multimedia presentations on a computer, you need to have certain tools. These may include traditional graphic tools and drawing programs, animation programs, and authoring systems that tie everything together. Your computer will tell you which tools it supports. The most important step is to learn about the tools that you will be using.

- Often, color and strong images will convey a point better than words alone. Use the best methods available to convey your point.
- As with other presentations, practice many times.
- Practice your presentation with the tools you and any assistants will be using.
- Maintain eye contact with the audience. The purpose of using the computer is not to prompt the presenter, but to help the audience understand the points of the presentation.

Davis Barber/PhotoEdit, Inc.

Math Review

Use Fractions

A fraction compares a part to a whole. In the fraction $\frac{2}{3}$, the 2 represents the part and is the numerator. The 3 represents the whole and is the denominator.

Reduce Fractions To reduce a fraction, you must find the largest factor that is common to both the numerator and the denominator, the greatest common factor (GCF). Divide both numbers by the GCF. The fraction has then been reduced, or it is in its simplest form.

Example Twelve of the 20 chemicals in the science lab are in powder form. What fraction of the chemicals used in the lab are in powder form?

Step 1 Write the fraction.

$$\frac{\text{part}}{\text{whole}} = \frac{12}{20}$$

Step 2 To find the GCF of the numerator and denominator, list all of the factors of each number.

Factors of 12: 1, 2, 3, 4, 6, 12 (the numbers that divide evenly into 12)

Factors of 20: 1, 2, 4, 5, 10, 20 (the numbers that divide evenly into 20)

Step 3 List the common factors.

1, 2, 4.

Step 4 Choose the greatest factor in the list.

The GCF of 12 and 20 is 4.

Step 5 Divide the numerator and denominator by the GCF.

$$\frac{12 \div 4}{20 \div 4} = \frac{3}{5}$$

In the lab, $\frac{3}{5}$ of the chemicals are in powder form.

Practice Problem At an amusement park, 66 of 90 rides have a height restriction. What fraction of the rides, in its simplest form, has a height restriction?

Add and Subtract Fractions To add or subtract fractions with the same denominator, add or subtract the numerators and write the sum or difference over the denominator. After finding the sum or difference, find the simplest form for your fraction.

Example 1 In the forest outside your house, $\frac{1}{8}$ of the animals are rabbits, $\frac{3}{8}$ are squirrels, and the remainder are birds and insects. How many are mammals?

Step 1 Add the numerators.

$$\frac{1}{8} + \frac{3}{8} = \frac{(1 + 3)}{8} = \frac{4}{8}$$

Step 2 Find the GCF.

$$\frac{4}{8} \quad \text{(GCF, 4)}$$

Step 3 Divide the numerator and denominator by the GCF.

$$\frac{4}{4} = 1, \quad \frac{8}{4} = 2$$

$\frac{1}{2}$ of the animals are mammals.

Example 2 If $\frac{7}{16}$ of the Earth is covered by freshwater, and $\frac{1}{16}$ of that is in glaciers, how much freshwater is not frozen?

Step 1 Subtract the numerators.

$$\frac{7}{16} - \frac{1}{16} = \frac{(7 - 1)}{16} = \frac{6}{16}$$

Step 2 Find the GCF.

$$\frac{6}{16} \quad \text{(GCF, 2)}$$

Step 3 Divide the numerator and denominator by the GCF.

$$\frac{6}{2} = 3, \quad \frac{16}{2} = 8$$

$\frac{3}{8}$ of the freshwater is not frozen.

Practice Problem A bicycle rider is going 15 km/h for $\frac{4}{9}$ of his ride, 10 km/h for $\frac{2}{9}$ of his ride, and 8 km/h for the remainder of the ride. How much of his ride is he going over 8 km/h?

Unlike Denominators To add or subtract fractions with unlike denominators, first find the least common denominator (LCD). This is the smallest number that is a common multiple of both denominators. Rename each fraction with the LCD, and then add or subtract. Find the simplest form if necessary.

Example 1 A chemist makes a paste that is $\frac{1}{2}$ table salt (NaCl), $\frac{1}{3}$ sugar ($C_6H_{12}O_6$), and the rest water (H_2O). How much of the paste is a solid?

Step 1 Find the LCD of the fractions.

$\frac{1}{2} + \frac{1}{3}$ (LCD, 6)

Step 2 Rename each numerator and each denominator with the LCD.

$1 \times 3 = 3,\ 2 \times 3 = 6$

$1 \times 2 = 2,\ 3 \times 2 = 6$

Step 3 Add the numerators.

$\frac{3}{6} + \frac{2}{6} = \frac{(3+2)}{6} = \frac{5}{6}$

$\frac{5}{6}$ of the paste is a solid.

Example 2 The average precipitation in Grand Junction, CO, is $\frac{7}{10}$ inch in November, and $\frac{3}{5}$ inch in December. What is the total average precipitation?

Step 1 Find the LCD of the fractions.

$\frac{7}{10} + \frac{3}{5}$ (LCD, 10)

Step 2 Rename each numerator and each denominator with the LCD.

$7 \times 1 = 7,\ 10 \times 1 = 10$

$3 \times 2 = 6,\ 5 \times 2 = 10$

Step 3 Add the numerators.

$\frac{7}{10} + \frac{6}{10} = \frac{(7+6)}{10} = \frac{13}{10}$

$\frac{13}{10}$ inches total precipitation, or $1\frac{3}{10}$ inches.

Practice Problem On an electric bill, about $\frac{1}{8}$ of the energy is from solar energy and about $\frac{1}{10}$ is from wind power. How much of the total bill is from solar energy and wind power combined?

Example 3 In your body, $\frac{7}{10}$ of your muscle contractions are involuntary (cardiac and smooth muscle tissue). Smooth muscle makes $\frac{3}{15}$ of your muscle contractions. How many of your muscle contractions are made by cardiac muscle?

Step 1 Find the LCD of the fractions.

$\frac{7}{10} - \frac{3}{15}$ (LCD, 30)

Step 2 Rename each numerator and each denominator with the LCD.

$7 \times 3 = 21,\ 10 \times 3 = 30$

$3 \times 2 = 6,\ 15 \times 2 = 30$

Step 3 Subtract the numerators.

$\frac{21}{30} - \frac{6}{30} = \frac{(21-6)}{30} = \frac{15}{30}$

Step 4 Find the GCF.

$\frac{15}{30}$ (GCF, 15)

$\frac{1}{2}$

$\frac{1}{2}$ of all muscle contractions are cardiac muscle.

Example 4 Tony wants to make cookies that call for $\frac{3}{4}$ of a cup of flour, but he only has $\frac{1}{3}$ of a cup. How much more flour does he need?

Step 1 Find the LCD of the fractions.

$\frac{3}{4} - \frac{1}{3}$ (LCD, 12)

Step 2 Rename each numerator and each denominator with the LCD.

$3 \times 3 = 9,\ 4 \times 3 = 12$

$1 \times 4 = 4,\ 3 \times 4 = 12$

Step 3 Subtract the numerators.

$\frac{9}{12} - \frac{4}{12} = \frac{(9-4)}{12} = \frac{5}{12}$

$\frac{5}{12}$ of a cup of flour.

Practice Problem Using the information provided to you in Example 3 above, determine how many muscle contractions are voluntary (skeletal muscle).

Multiply Fractions To multiply with fractions, multiply the numerators and multiply the denominators. Find the simplest form if necessary.

Example Multiply $\frac{3}{5}$ by $\frac{1}{3}$.

Step 1 Multiply the numerators and denominators.

$$\frac{3}{5} \times \frac{1}{3} = \frac{(3 \times 1)}{(5 \times 3)} = \frac{3}{15}$$

Step 2 Find the GCF.

$$\frac{3}{15} \quad (\text{GCF}, 3)$$

Step 3 Divide the numerator and denominator by the GCF.

$$\frac{3}{3} = 1, \quad \frac{15}{3} = 5$$

$$\frac{1}{5}$$

$\frac{3}{5}$ multiplied by $\frac{1}{3}$ is $\frac{1}{5}$.

Practice Problem Multiply $\frac{3}{14}$ by $\frac{5}{16}$.

Find a Reciprocal Two numbers whose product is 1 are called multiplicative inverses, or reciprocals.

Example Find the reciprocal of $\frac{3}{8}$.

Step 1 Inverse the fraction by putting the denominator on top and the numerator on the bottom.

$$\frac{8}{3}$$

The reciprocal of $\frac{3}{8}$ is $\frac{8}{3}$.

Practice Problem Find the reciprocal of $\frac{4}{9}$.

Divide Fractions To divide one fraction by another fraction, multiply the dividend by the reciprocal of the divisor. Find the simplest form if necessary.

Example 1 Divide $\frac{1}{9}$ by $\frac{1}{3}$.

Step 1 Find the reciprocal of the divisor.

The reciprocal of $\frac{1}{3}$ is $\frac{3}{1}$.

Step 2 Multiply the dividend by the reciprocal of the divisor.

$$\frac{\frac{1}{9}}{\frac{1}{3}} = \frac{1}{9} \times \frac{3}{1} = \frac{(1 \times 3)}{(9 \times 1)} = \frac{3}{9}$$

Step 3 Find the GCF.

$$\frac{3}{9} \quad (\text{GCF}, 3)$$

Step 4 Divide the numerator and denominator by the GCF.

$$\frac{3}{3} = 1, \quad \frac{9}{3} = 3$$

$$\frac{1}{3}$$

$\frac{1}{9}$ divided by $\frac{1}{3}$ is $\frac{1}{3}$.

Example 2 Divide $\frac{3}{5}$ by $\frac{1}{4}$.

Step 1 Find the reciprocal of the divisor.

The reciprocal of $\frac{1}{4}$ is $\frac{4}{1}$.

Step 2 Multiply the dividend by the reciprocal of the divisor.

$$\frac{\frac{3}{5}}{\frac{1}{4}} = \frac{3}{5} \times \frac{4}{1} = \frac{(3 \times 4)}{(5 \times 1)} = \frac{12}{5}$$

$\frac{3}{5}$ divided by $\frac{1}{4}$ is $\frac{12}{5}$ or $2\frac{2}{5}$.

Practice Problem Divide $\frac{3}{11}$ by $\frac{7}{10}$.

Use Ratios

When you compare two numbers by division, you are using a ratio. Ratios can be written 3 to 5, 3:5, or $\frac{3}{5}$. Ratios, like fractions, also can be written in simplest form.

Ratios can represent probabilities, also called odds. This is a ratio that compares the number of ways a certain outcome occurs to the number of outcomes. For example, if you flip a coin 100 times, what are the odds that it will come up heads? There are two possible outcomes, heads or tails, so the odds of coming up heads are 50:100. Another way to say this is that 50 out of 100 times the coin will come up heads. In its simplest form, the ratio is 1:2.

Example 1 A chemical solution contains 40 g of salt and 64 g of baking soda. What is the ratio of salt to baking soda as a fraction in simplest form?

Step 1 Write the ratio as a fraction.

$$\frac{\text{salt}}{\text{baking soda}} = \frac{40}{64}$$

Step 2 Express the fraction in simplest form.

The GCF of 40 and 64 is 8.

$$\frac{40}{64} = \frac{40 \div 8}{64 \div 8} = \frac{5}{8}$$

The ratio of salt to baking soda in the sample is 5:8.

Example 2 Sean rolls a 6-sided die 6 times. What are the odds that the side with a 3 will show?

Step 1 Write the ratio as a fraction.

$$\frac{\text{number of sides with a 3}}{\text{number of sides}} = \frac{1}{6}$$

Step 2 Multiply by the number of attempts.

$$\frac{1}{6} \times 6 \text{ attempts} = \frac{6}{6} \text{ attempts} = 1 \text{ attempt}$$

1 attempt out of 6 will show a 3.

Practice Problem Two metal rods measure 100 cm and 144 cm in length. What is the ratio of their lengths in simplest form?

Use Decimals

A fraction with a denominator that is a power of ten can be written as a decimal. For example, 0.27 means $\frac{27}{100}$. The decimal point separates the ones place from the tenths place.

Any fraction can be written as a decimal using division. For example, the fraction $\frac{5}{8}$ can be written as a decimal by dividing 5 by 8. Written as a decimal, it is 0.625.

Add or Subtract Decimals When adding and subtracting decimals, line up the decimal points before carrying out the operation.

Example 1 Find the sum of 47.68 and 7.80.

Step 1 Line up the decimal places when you write the numbers.

$$\begin{array}{r} 47.68 \\ +\ 7.80 \\ \hline \end{array}$$

Step 2 Add the decimals.

$$\begin{array}{r} 47.68 \\ +\ 7.80 \\ \hline 55.48 \end{array}$$

The sum of 47.68 and 7.80 is 55.48.

Example 2 Find the difference of 42.17 and 15.85.

Step 1 Line up the decimal places when you write the number.

$$\begin{array}{r} 42.17 \\ -15.85 \\ \hline \end{array}$$

Step 2 Subtract the decimals.

$$\begin{array}{r} 42.17 \\ -15.85 \\ \hline 26.32 \end{array}$$

The difference of 42.17 and 15.85 is 26.32.

Practice Problem Find the sum of 1.245 and 3.842.

Multiply Decimals To multiply decimals, multiply the numbers like any other number, ignoring the decimal point. Count the decimal places in each factor. The product will have the same number of decimal places as the sum of the decimal places in the factors.

Example Multiply 2.4 by 5.9.

Step 1 Multiply the factors like two whole numbers.
$24 \times 59 = 1416$

Step 2 Find the sum of the number of decimal places in the factors. Each factor has one decimal place, for a sum of two decimal places.

Step 3 The product will have two decimal places.
14.16

The product of 2.4 and 5.9 is 14.16.

Practice Problem Multiply 4.6 by 2.2.

Divide Decimals When dividing decimals, change the divisor to a whole number. To do this, multiply both the divisor and the dividend by the same power of ten. Then place the decimal point in the quotient directly above the decimal point in the dividend. Then divide as you do with whole numbers.

Example Divide 8.84 by 3.4.

Step 1 Multiply both factors by 10.
$3.4 \times 10 = 34,\ 8.84 \times 10 = 88.4$

Step 2 Divide 88.4 by 34.

$$\begin{array}{r} 2.6 \\ 34\overline{)88.4} \\ -68 \\ \hline 20\,4 \\ -20\,4 \\ \hline 0 \end{array}$$

8.84 divided by 3.4 is 2.6.

Practice Problem Divide 75.6 by 3.6.

Use Proportions

An equation that shows that two ratios are equivalent is a proportion. The ratios $\frac{2}{4}$ and $\frac{5}{10}$ are equivalent, so they can be written as $\frac{2}{4} = \frac{5}{10}$. This equation is a proportion.

When two ratios form a proportion, the cross products are equal. To find the cross products in the proportion $\frac{2}{4} = \frac{5}{10}$, multiply the 2 and the 10, and the 4 and the 5. Therefore $2 \times 10 = 4 \times 5$, or $20 = 20$.

Because you know that both proportions are equal, you can use cross products to find a missing term in a proportion. This is known as solving the proportion.

Example The heights of a tree and a pole are proportional to the lengths of their shadows. The tree casts a shadow of 24 m when a 6-m pole casts a shadow of 4 m. What is the height of the tree?

Step 1 Write a proportion.
$$\frac{\text{height of tree}}{\text{height of pole}} = \frac{\text{length of tree's shadow}}{\text{length of pole's shadow}}$$

Step 2 Substitute the known values into the proportion. Let h represent the unknown value, the height of the tree.
$$\frac{h}{6} = \frac{24}{4}$$

Step 3 Find the cross products.
$h \times 4 = 6 \times 24$

Step 4 Simplify the equation.
$4h = 144$

Step 5 Divide each side by 4.
$$\frac{4h}{4} = \frac{144}{4}$$
$h = 36$

The height of the tree is 36 m.

Practice Problem The ratios of the weights of two objects on the Moon and on Earth are in proportion. A rock weighing 3 N on the Moon weighs 18 N on Earth. How much would a rock that weighs 5 N on the Moon weigh on Earth?

Use Percentages

The word *percent* means "out of one hundred." It is a ratio that compares a number to 100. Suppose you read that 77 percent of the Earth's surface is covered by water. That is the same as reading that the fraction of the Earth's surface covered by water is $\frac{77}{100}$. To express a fraction as a percent, first find the equivalent decimal for the fraction. Then, multiply the decimal by 100 and add the percent symbol.

Example Express $\frac{13}{20}$ as a percent.

Step 1 Find the equivalent decimal for the fraction.

$$\begin{array}{r} 0.65 \\ 20\overline{)13.00} \\ \underline{12\ 0} \\ 1\ 00 \\ \underline{1\ 00} \\ 0 \end{array}$$

Step 2 Rewrite the fraction $\frac{13}{20}$ as 0.65.

Step 3 Multiply 0.65 by 100 and add the % sign.

$0.65 \times 100 = 65 = 65\%$

So, $\frac{13}{20} = 65\%$.

This also can be solved as a proportion.

Example Express $\frac{13}{20}$ as a percent.

Step 1 Write a proportion.

$\frac{13}{20} = \frac{x}{100}$

Step 2 Find the cross products.

$1300 = 20x$

Step 3 Divide each side by 20.

$\frac{1300}{20} = \frac{20x}{20}$

$65\% = x$

Practice Problem In one year, 73 of 365 days were rainy in one city. What percent of the days in that city were rainy?

Solve One-Step Equations

A statement that two things are equal is an equation. For example, $A = B$ is an equation that states that A is equal to B.

An equation is solved when a variable is replaced with a value that makes both sides of the equation equal. To make both sides equal the inverse operation is used. Addition and subtraction are inverses, and multiplication and division are inverses.

Example 1 Solve the equation $x - 10 = 35$.

Step 1 Find the solution by adding 10 to each side of the equation.

$x - 10 = 35$

$x - 10 + 10 = 35 + 10$

$x = 45$

Step 2 Check the solution.

$x - 10 = 35$

$45 - 10 = 35$

$35 = 35$

Both sides of the equation are equal, so $x = 45$.

Example 2 In the formula $a = bc$, find the value of c if $a = 20$ and $b = 2$.

Step 1 Rearrange the formula so the unknown value is by itself on one side of the equation by dividing both sides by *b*.

$a = bc$

$\frac{a}{b} = \frac{bc}{b}$

$\frac{a}{b} = c$

Step 2 Replace the variables *a* and *b* with the values that are given.

$\frac{a}{b} = c$

$\frac{20}{2} = c$

$10 = c$

Step 3 Check the solution.

$a = bc$

$20 = 2 \times 10$

$20 = 20$

Both sides of the equation are equal, so $c = 10$ is the solution when $a = 20$ and $b = 2$.

Practice Problem In the formula $h = gd$, find the value of d if $g = 12.3$ and $h = 17.4$.

Use Statistics

The branch of mathematics that deals with collecting, analyzing, and presenting data is statistics. In statistics, there are three common ways to summarize data with a single number—the mean, the median, and the mode.

The **mean** of a set of data is the arithmetic average. It is found by adding the numbers in the data set and dividing by the number of items in the set.

The **median** is the middle number in a set of data when the data are arranged in numerical order. If there were an even number of data points, the median would be the mean of the two middle numbers.

The **mode** of a set of data is the number or item that appears most often.

Another number that often is used to describe a set of data is the range. The **range** is the difference between the largest number and the smallest number in a set of data.

A **frequency table** shows how many times each piece of data occurs, usually in a survey. **Table 2** below shows the results of a student survey on favorite color.

Table 2 Student Color Choice

Color	Tally	Frequency
red	||||	4
blue	~~||||~~	5
black	||	2
green	|||	3
purple	~~||||~~ ||	7
yellow	~~||||~~ |	6

Based on the frequency table data, which color is the favorite?

Example The speeds (in m/s) for a race car during five different time trials are 39, 37, 44, 36, and 44.

To find the mean:

Step 1 Find the sum of the numbers.

$39 + 37 + 44 + 36 + 44 = 200$

Step 2 Divide the sum by the number of items, which is 5.

$200 \div 5 = 40$

The mean is 40 m/s.

To find the median:

Step 1 Arrange the measures from least to greatest.

36, 37, 39, 44, 44

Step 2 Determine the middle measure.

36, 37, <u>39</u>, 44, 44

The median is 39 m/s.

To find the mode:

Step 1 Group the numbers that are the same together.

44, 44, 36, 37, 39

Step 2 Determine the number that occurs most in the set.

<u>44, 44</u>, 36, 37, 39

The mode is 44 m/s.

To find the range:

Step 1 Arrange the measures from largest to smallest.

44, 44, 39, 37, 36

Step 2 Determine the largest and smallest measures in the set.

<u>44</u>, 44, 39, 37, <u>36</u>

Step 3 Find the difference between the largest and smallest measures.

$44 - 36 = 8$

The range is 8 m/s.

Practice Problem Find the mean, median, mode, and range for the data set 8, 4, 12, 8, 11, 14, 16.

Use Geometry

The branch of mathematics that deals with the measurement, properties, and relationships of points, lines, angles, surfaces, and solids is called geometry.

Perimeter The **perimeter** (P) is the distance around a geometric figure. To find the perimeter of a rectangle, add the length and width and multiply that sum by two, or $2(l + w)$. To find perimeters of irregular figures, add the length of the sides.

Example 1 Find the perimeter of a rectangle that is 3 m long and 5 m wide.

Step 1 You know that the perimeter is 2 times the sum of the width and length.
$P = 2(3\text{ m} + 5\text{ m})$

Step 2 Find the sum of the width and length.
$P = 2(8\text{ m})$

Step 3 Multiply by 2.
$P = 16\text{ m}$

The perimeter is 16 m.

Example 2 Find the perimeter of a shape with sides measuring 2 cm, 5 cm, 6 cm, 3 cm.

Step 1 You know that the perimeter is the sum of all the sides.
$P = 2 + 5 + 6 + 3$

Step 2 Find the sum of the sides.
$P = 2 + 5 + 6 + 3$
$P = 16$

The perimeter is 16 cm.

Practice Problem Find the perimeter of a rectangle with a length of 18 m and a width of 7 m.

Practice Problem Find the perimeter of a triangle measuring 1.6 cm by 2.4 cm by 2.4 cm.

Area of a Rectangle The **area** (A) is the number of square units needed to cover a surface. To find the area of a rectangle, multiply the length times the width, or $l \times w$. When finding area, the units also are multiplied. Area is given in square units.

Example Find the area of a rectangle with a length of 1 cm and a width of 10 cm.

Step 1 You know that the area is the length multiplied by the width.
$A = (1\text{ cm} \times 10\text{ cm})$

Step 2 Multiply the length by the width. Also multiply the units.
$A = 10\text{ cm}^2$

The area is 10 cm^2.

Practice Problem Find the area of a square whose sides measure 4 m.

Area of a Triangle To find the area of a triangle, use the formula:

$$A = \frac{1}{2}(\text{base} \times \text{height})$$

The base of a triangle can be any of its sides. The height is the perpendicular distance from a base to the opposite endpoint, or vertex.

Example Find the area of a triangle with a base of 18 m and a height of 7 m.

Step 1 You know that the area is $\frac{1}{2}$ the base times the height.
$A = \frac{1}{2}(18\text{ m} \times 7\text{ m})$

Step 2 Multiply $\frac{1}{2}$ by the product of 18×7. Multiply the units.
$A = \frac{1}{2}(126\text{ m}^2)$
$A = 63\text{ m}^2$

The area is 63 m^2.

Practice Problem Find the area of a triangle with a base of 27 cm and a height of 17 cm.

Circumference of a Circle The **diameter** (d) of a circle is the distance across the circle through its center, and the **radius** (r) is the distance from the center to any point on the circle. The radius is half of the diameter. The distance around the circle is called the **circumference** (C). The formula for finding the circumference is:

$$C = 2\pi r \quad or \quad C = \pi d$$

The circumference divided by the diameter is always equal to 3.1415926... This nonterminating and nonrepeating number is represented by the Greek letter π (pi). An approximation often used for π is 3.14.

Example 1 Find the circumference of a circle with a radius of 3 m.

Step 1 You know the formula for the circumference is 2 times the radius times π.
$C = 2\pi(3)$

Step 2 Multiply 2 times the radius.
$C = 6\pi$

Step 3 Multiply by π.
$C = 19$ m

The circumference is 19 m.

Example 2 Find the circumference of a circle with a diameter of 24.0 cm.

Step 1 You know the formula for the circumference is the diameter times π.
$C = \pi(24.0)$

Step 2 Multiply the diameter by π.
$C = 75.4$ cm

The circumference is 75.4 cm.

Practice Problem Find the circumference of a circle with a radius of 19 cm.

Area of a Circle The formula for the area of a circle is:
$A = \pi r^2$

Example 1 Find the area of a circle with a radius of 4.0 cm.

Step 1 $A = \pi(4.0)^2$

Step 2 Find the square of the radius.
$A = 16\pi$

Step 3 Multiply the square of the radius by π.
$A = 50\ cm^2$

The area of the circle is 50 cm^2.

Example 2 Find the area of a circle with a radius of 225 m.

Step 1 $A = \pi(225)^2$

Step 2 Find the square of the radius.
$A = 50625\pi$

Step 3 Multiply the square of the radius by π.
$A = 158962.5$

The area of the circle is 158,962 m^2.

Example 3 Find the area of a circle whose diameter is 20.0 mm.

Step 1 You know the formula for the area of a circle is the square of the radius times π, and that the radius is half of the diameter.
$A = \pi\left(\frac{20.0}{2}\right)^2$

Step 2 Find the radius.
$A = \pi(10.0)^2$

Step 3 Find the square of the radius.
$A = 100\pi$

Step 4 Multiply the square of the radius by π.
$A = 314\ mm^2$

The area is 314 mm^2.

Practice Problem Find the area of a circle with a radius of 16 m.

Volume The measure of space occupied by a solid is the **volume** (V). To find the volume of a rectangular solid multiply the length times width times height, or $V = l \times w \times h$. It is measured in cubic units, such as cubic centimeters (cm^3).

Example Find the volume of a rectangular solid with a length of 2.0 m, a width of 4.0 m, and a height of 3.0 m.

Step 1 You know the formula for volume is the length times the width times the height.
$V = 2.0\text{ m} \times 4.0\text{ m} \times 3.0\text{ m}$

Step 2 Multiply the length times the width times the height.
$V = 24\text{ m}^3$

The volume is 24 m^3.

Practice Problem Find the volume of a rectangular solid that is 8 m long, 4 m wide, and 4 m high.

To find the volume of other solids, multiply the area of the base times the height.

Example 1 Find the volume of a solid that has a triangular base with a length of 8.0 m and a height of 7.0 m. The height of the entire solid is 15.0 m.

Step 1 You know that the base is a triangle, and the area of a triangle is $\frac{1}{2}$ the base times the height, and the volume is the area of the base times the height.
$V = \left[\frac{1}{2}(b \times h)\right] \times 15$

Step 2 Find the area of the base.
$V = \left[\frac{1}{2}(8 \times 7)\right] \times 15$
$V = \left(\frac{1}{2} \times 56\right) \times 15$

Step 3 Multiply the area of the base by the height of the solid.
$V = 28 \times 15$
$V = 420\text{ m}^3$

The volume is 420 m^3.

Example 2 Find the volume of a cylinder that has a base with a radius of 12.0 cm, and a height of 21.0 cm.

Step 1 You know that the base is a circle, and the area of a circle is the square of the radius times π, and the volume is the area of the base times the height.
$V = (\pi r^2) \times 21$
$V = (\pi 12^2) \times 21$

Step 2 Find the area of the base.
$V = 144\pi \times 21$
$V = 452 \times 21$

Step 3 Multiply the area of the base by the height of the solid.
$V = 9490\text{ cm}^3$

The volume is 9490 cm^3.

Example 3 Find the volume of a cylinder that has a diameter of 15 mm and a height of 4.8 mm.

Step 1 You know that the base is a circle with an area equal to the square of the radius times π. The radius is one-half the diameter. The volume is the area of the base times the height.
$V = (\pi r^2) \times 4.8$
$V = \left[\pi\left(\frac{1}{2} \times 15\right)^2\right] \times 4.8$
$V = (\pi 7.5^2) \times 4.8$

Step 2 Find the area of the base.
$V = 56.25\pi \times 4.8$
$V = 176.63 \times 4.8$

Step 3 Multiply the area of the base by the height of the solid.
$V = 847.8$

The volume is 847.8 mm^3.

Practice Problem Find the volume of a cylinder with a diameter of 7 cm in the base and a height of 16 cm.

Science Applications

Measure in SI

The metric system of measurement was developed in 1795. A modern form of the metric system, called the International System (SI), was adopted in 1960 and provides the standard measurements that all scientists around the world can understand.

The SI system is convenient because unit sizes vary by powers of 10. Prefixes are used to name units. Look at **Table 3** for some common SI prefixes and their meanings.

Table 3 Common SI Prefixes

Prefix	Symbol	Meaning	
kilo-	k	1,000	thousand
hecto-	h	100	hundred
deka-	da	10	ten
deci-	d	0.1	tenth
centi-	c	0.01	hundredth
milli-	m	0.001	thousandth

Example How many grams equal one kilogram?

Step 1 Find the prefix *kilo* in **Table 3.**

Step 2 Using **Table 3,** determine the meaning of *kilo.* According to the table, it means 1,000. When the prefix *kilo* is added to a unit, it means that there are 1,000 of the units in a "*kilo*unit."

Step 3 Apply the prefix to the units in the question. The units in the question are grams. There are 1,000 grams in a kilogram.

Practice Problem Is a milligram larger or smaller than a gram? How many of the smaller units equal one larger unit? What fraction of the larger unit does one smaller unit represent?

Dimensional Analysis

Convert SI Units In science, quantities such as length, mass, and time sometimes are measured using different units. A process called dimensional analysis can be used to change one unit of measure to another. This process involves multiplying your starting quantity and units by one or more conversion factors. A conversion factor is a ratio equal to one and can be made from any two equal quantities with different units. If 1,000 mL equal 1 L then two ratios can be made.

$$\frac{1{,}000 \text{ mL}}{1 \text{ L}} = \frac{1 \text{ L}}{1{,}000 \text{ mL}} = 1$$

One can covert between units in the SI system by using the equivalents in **Table 3** to make conversion factors.

Example 1 How many cm are in 4 m?

Step 1 Write conversion factors for the units given. From **Table 3,** you know that 100 cm = 1 m. The conversion factors are

$$\frac{100 \text{ cm}}{1 \text{ m}} \textit{ and } \frac{1 \text{ m}}{100 \text{ cm}}$$

Step 2 Decide which conversion factor to use. Select the factor that has the units you are converting from (m) in the denominator and the units you are converting to (cm) in the numerator.

$$\frac{100 \text{ cm}}{1 \text{ m}}$$

Step 3 Multiply the starting quantity and units by the conversion factor. Cancel the starting units with the units in the denominator. There are 400 cm in 4 m.

$$4 \cancel{\text{m}} \times \frac{100 \text{ cm}}{1 \cancel{\text{m}}} = 400 \text{ cm}$$

Practice Problem How many milligrams are in one kilogram? (Hint: You will need to use two conversion factors from **Table 3.**)

Table 4 Unit System Equivalents

Type of Measurement	Equivalent
Length	1 in = 2.54 cm 1 yd = 0.91 m 1 mi = 1.61 km
Mass and Weight*	1 oz = 28.35 g 1 lb = 0.45 kg 1 ton (short) = 0.91 tonnes (metric tons) 1 lb = 4.45 N
Volume	1 in^3 = 16.39 cm^3 1 qt = 0.95 L 1 gal = 3.78 L
Area	1 in^2 = 6.45 cm^2 1 yd^2 = 0.83 m^2 1 mi^2 = 2.59 km^2 1 acre = 0.40 hectares
Temperature	$°C = \frac{(°F - 32)}{1.8}$ K = °C + 273

*Weight is measured in standard Earth gravity.

Convert Between Unit Systems **Table 4** gives a list of equivalents that can be used to convert between English and SI units.

Example If a meterstick has a length of 100 cm, how long is the meterstick in inches?

Step 1 Write the conversion factors for the units given. From **Table 4,** 1 in = 2.54 cm.

$$\frac{1\text{ in}}{2.54\text{ cm}} \quad \textit{and} \quad \frac{2.54\text{ cm}}{1\text{ in}}$$

Step 2 Determine which conversion factor to use. You are converting from cm to in. Use the conversion factor with cm on the bottom.

$$\frac{1\text{ in}}{2.54\text{ cm}}$$

Step 3 Multiply the starting quantity and units by the conversion factor. Cancel the starting units with the units in the denominator. Round your answer based on the number of significant figures in the conversion factor.

$$100\ \cancel{\text{cm}} \times \frac{1\text{ in}}{2.54\ \cancel{\text{cm}}} = 39.37\text{ in}$$

The meterstick is 39.4 in long.

Practice Problem A book has a mass of 5 lbs. What is the mass of the book in kg?

Practice Problem Use the equivalent for in and cm (1 in = 2.54 cm) to show how 1 in^3 = 16.39 cm^3.

Precision and Significant Digits

When you make a measurement, the value you record depends on the precision of the measuring instrument. This precision is represented by the number of significant digits recorded in the measurement. When counting the number of significant digits, all digits are counted except zeros at the end of a number with no decimal point such as 2,050, and zeros at the beginning of a decimal such as 0.03020. When adding or subtracting numbers with different precision, round the answer to the smallest number of decimal places of any number in the sum or difference. When multiplying or dividing, the answer is rounded to the smallest number of significant digits of any number being multiplied or divided.

Example The lengths 5.28 and 5.2 are measured in meters. Find the sum of these lengths and record your answer using the correct number of significant digits.

Step 1 Find the sum.

5.28 m	2 digits after the decimal
+ 5.2 m	1 digit after the decimal
10.48 m	

Step 2 Round to one digit after the decimal because the least number of digits after the decimal of the numbers being added is 1.

The sum is 10.5 m.

Practice Problem How many significant digits are in the measurement 7,071,301 m? How many significant digits are in the measurement 0.003010 g?

Practice Problem Multiply 5.28 and 5.2 using the rule for multiplying and dividing. Record the answer using the correct number of significant digits.

Scientific Notation

Many times numbers used in science are very small or very large. Because these numbers are difficult to work with scientists use scientific notation. To write numbers in scientific notation, move the decimal point until only one non-zero digit remains on the left. Then count the number of places you moved the decimal point and use that number as a power of ten. For example, the average distance from the Sun to Mars is 227,800,000,000 m. In scientific notation, this distance is 2.278×10^{11} m. Because you moved the decimal point to the left, the number is a positive power of ten.

The mass of an electron is about 0.000 000 000 000 000 000 000 000 000 000 911 kg. Expressed in scientific notation, this mass is 9.11×10^{-31} kg. Because the decimal point was moved to the right, the number is a negative power of ten.

Example Earth is 149,600,000 km from the Sun. Express this in scientific notation.

Step 1 Move the decimal point until one non-zero digit remains on the left.

1.496 000 00

Step 2 Count the number of decimal places you have moved. In this case, eight.

Step 3 Show that number as a power of ten, 10^8.

The Earth is 1.496×10^8 km from the Sun.

Practice Problem How many significant digits are in 149,600,000 km? How many significant digits are in 1.496×10^8 km?

Practice Problem Parts used in a high performance car must be measured to 7×10^{-6} m. Express this number as a decimal.

Practice Problem A CD is spinning at 539 revolutions per minute. Express this number in scientific notation.

Math Skill Handbook

Make and Use Graphs

Data in tables can be displayed in a graph—a visual representation of data. Common graph types include line graphs, bar graphs, and circle graphs.

Line Graph A line graph shows a relationship between two variables that change continuously. The independent variable is changed and is plotted on the *x*-axis. The dependent variable is observed, and is plotted on the *y*-axis.

Example Draw a line graph of the data below from a cyclist in a long-distance race.

Table 5 Bicycle Race Data

Time (h)	Distance (km)
0	0
1	8
2	16
3	24
4	32
5	40

Step 1 Determine the *x*-axis and *y*-axis variables. Time varies independently of distance and is plotted on the *x*-axis. Distance is dependent on time and is plotted on the *y*-axis.

Step 2 Determine the scale of each axis. The *x*-axis data ranges from 0 to 5. The *y*-axis data ranges from 0 to 40.

Step 3 Using graph paper, draw and label the axes. Include units in the labels.

Step 4 Draw a point at the intersection of the time value on the *x*-axis and corresponding distance value on the *y*-axis. Connect the points and label the graph with a title, as shown in **Figure 20.**

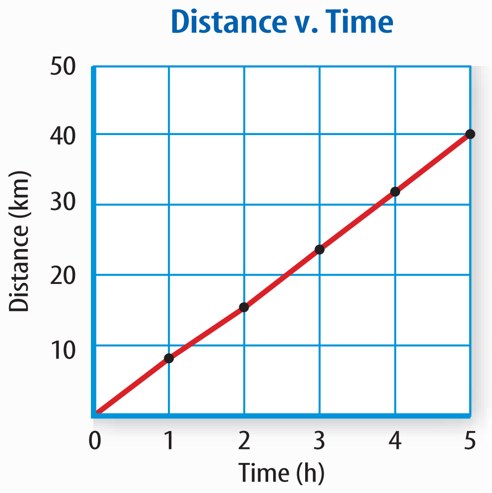


Figure 20 This line graph shows the relationship between distance and time during a bicycle ride.

Practice Problem A puppy's shoulder height is measured during the first year of her life. The following measurements were collected: (3 mo, 52 cm), (6 mo, 72 cm), (9 mo, 83 cm), (12 mo, 86 cm). Graph this data.

Find a Slope The slope of a straight line is the ratio of the vertical change, rise, to the horizontal change, run.

$$\text{Slope} = \frac{\text{vertical change (rise)}}{\text{horizontal change (run)}} = \frac{\text{change in } y}{\text{change in } x}$$

Example Find the slope of the graph in **Figure 20.**

Step 1 You know that the slope is the change in *y* divided by the change in *x*.

$$\text{Slope} = \frac{\text{change in } y}{\text{change in } x}$$

Step 2 Determine the data points you will be using. For a straight line, choose the two sets of points that are the farthest apart.

$$\text{Slope} = \frac{(40\text{–}0)\text{ km}}{(5\text{–}0)\text{ hr}}$$

Step 3 Find the change in *y* and *x*.

$$\text{Slope} = \frac{40\text{ km}}{5\text{h}}$$

Step 4 Divide the change in *y* by the change in *x*.

$$\text{Slope} = \frac{8\text{ km}}{\text{h}}$$

The slope of the graph is 8 km/h.

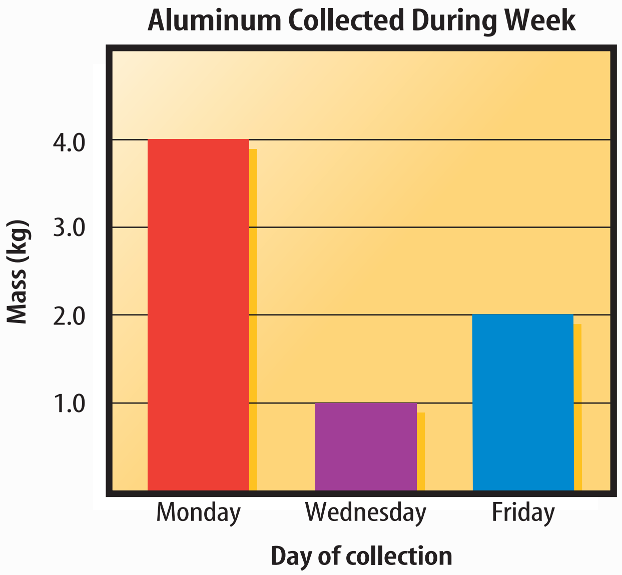
Bar Graph To compare data that does not change continuously you might choose a bar graph. A bar graph uses bars to show the relationships between variables. The *x*-axis variable is divided into parts. The parts can be numbers such as years, or a category such as a type of animal. The *y*-axis is a number and increases continuously along the axis.

Example A recycling center collects 4.0 kg of aluminum on Monday, 1.0 kg on Wednesday, and 2.0 kg on Friday. Create a bar graph of this data.

Step 1 Select the *x*-axis and *y*-axis variables. The measured numbers (the masses of aluminum) should be placed on the *y*-axis. The variable divided into parts (collection days) is placed on the *x*-axis.

Step 2 Create a graph grid like you would for a line graph. Include labels and units.

Step 3 For each measured number, draw a vertical bar above the *x*-axis value up to the *y*-axis value. For the first data point, draw a vertical bar above Monday up to 4.0 kg.



Practice Problem Draw a bar graph of the gases in air: 78% nitrogen, 21% oxygen, 1% other gases.

Circle Graph To display data as parts of a whole, you might use a circle graph. A circle graph is a circle divided into sections that represent the relative size of each piece of data. The entire circle represents 100%, half represents 50%, and so on.

Example Air is made up of 78% nitrogen, 21% oxygen, and 1% other gases. Display the composition of air in a circle graph.

Step 1 Multiply each percent by 360° and divide by 100 to find the angle of each section in the circle.

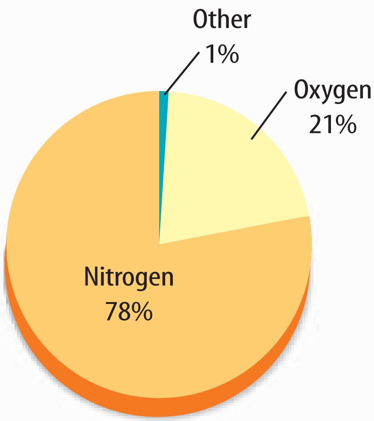
$$78\% \times \frac{360^\circ}{100} = 280.8^\circ$$

$$21\% \times \frac{360^\circ}{100} = 75.6^\circ$$

$$1\% \times \frac{360^\circ}{100} = 3.6^\circ$$

Step 2 Use a compass to draw a circle and to mark the center of the circle. Draw a straight line from the center to the edge of the circle.

Step 3 Use a protractor and the angles you calculated to divide the circle into parts. Place the center of the protractor over the center of the circle and line the base of the protractor over the straight line.



Practice Problem Draw a circle graph to represent the amount of aluminum collected during the week shown in the bar graph to the left.

PERIODIC TABLE OF THE ELEMENTS

Columns of elements are called groups. Elements in the same group have similar chemical properties.

Element — Hydrogen
Atomic number — 1
Symbol — H
Atomic mass — 1.008
State of matter

Gas
Liquid
Solid
Synthetic

The first three symbols tell you the state of matter of the element at room temperature. The fourth symbol identifies elements that are not present in significant amounts on Earth. Useful amounts are made synthetically.

	1	2	3	4	5	6	7	8	9
1	Hydrogen 1 H 1.008								
2	Lithium 3 Li 6.941	Beryllium 4 Be 9.012							
3	Sodium 11 Na 22.990	Magnesium 12 Mg 24.305							
4	Potassium 19 K 39.098	Calcium 20 Ca 40.078	Scandium 21 Sc 44.956	Titanium 22 Ti 47.867	Vanadium 23 V 50.942	Chromium 24 Cr 51.996	Manganese 25 Mn 54.938	Iron 26 Fe 55.845	Cobalt 27 Co 58.933
5	Rubidium 37 Rb 85.468	Strontium 38 Sr 87.62	Yttrium 39 Y 88.906	Zirconium 40 Zr 91.224	Niobium 41 Nb 92.906	Molybdenum 42 Mo 95.94	Technetium 43 Tc (98)	Ruthenium 44 Ru 101.07	Rhodium 45 Rh 102.906
6	Cesium 55 Cs 132.905	Barium 56 Ba 137.327	Lanthanum 57 La 138.906	Hafnium 72 Hf 178.49	Tantalum 73 Ta 180.948	Tungsten 74 W 183.84	Rhenium 75 Re 186.207	Osmium 76 Os 190.23	Iridium 77 Ir 192.217
7	Francium 87 Fr (223)	Radium 88 Ra (226)	Actinium 89 Ac (227)	Rutherfordium 104 Rf (261)	Dubnium 105 Db (262)	Seaborgium 106 Sg (266)	Bohrium 107 Bh (264)	Hassium 108 Hs (277)	Meitnerium 109 Mt (268)

The number in parentheses is the mass number of the longest-lived isotope for that element.

Rows of elements are called periods. Atomic number increases across a period.

The arrow shows where these elements would fit into the periodic table. They are moved to the bottom of the table to save space.

Lanthanide series	Cerium 58 Ce 140.116	Praseodymium 59 Pr 140.908	Neodymium 60 Nd 144.24	Promethium 61 Pm (145)	Samarium 62 Sm 150.36
Actinide series	Thorium 90 Th 232.038	Protactinium 91 Pa 231.036	Uranium 92 U 238.029	Neptunium 93 Np (237)	Plutonium 94 Pu (244)

Metal

Metalloid

Nonmetal

The color of an element's block tells you if the element is a metal, nonmetal, or metalloid.

Science Online

Visit bookb.msscience.com for updates to the periodic table.

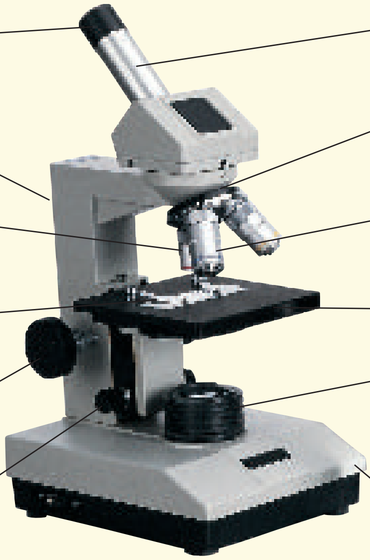
10	11	12	13	14	15	16	17	18
								Helium 2 He 4.003
			Boron 5 B 10.811	Carbon 6 C 12.011	Nitrogen 7 N 14.007	Oxygen 8 O 15.999	Fluorine 9 F 18.998	Neon 10 Ne 20.180
			Aluminum 13 Al 26.982	Silicon 14 Si 28.086	Phosphorus 15 P 30.974	Sulfur 16 S 32.065	Chlorine 17 Cl 35.453	Argon 18 Ar 39.948
Nickel 28 Ni 58.693	Copper 29 Cu 63.546	Zinc 30 Zn 65.409	Gallium 31 Ga 69.723	Germanium 32 Ge 72.64	Arsenic 33 As 74.922	Selenium 34 Se 78.96	Bromine 35 Br 79.904	Krypton 36 Kr 83.798
Palladium 46 Pd 106.42	Silver 47 Ag 107.868	Cadmium 48 Cd 112.411	Indium 49 In 114.818	Tin 50 Sn 118.710	Antimony 51 Sb 121.760	Tellurium 52 Te 127.60	Iodine 53 I 126.904	Xenon 54 Xe 131.293
Platinum 78 Pt 195.078	Gold 79 Au 196.967	Mercury 80 Hg 200.59	Thallium 81 Tl 204.383	Lead 82 Pb 207.2	Bismuth 83 Bi 208.980	Polonium 84 Po (209)	Astatine 85 At (210)	Radon 86 Rn (222)
Darmstadtium 110 Ds (281)	Unununium * 111 Uuu (272)	Ununbium * 112 Uub (285)		Ununquadium * 114 Uuq (289)		** 116		** 118

* The names and symbols for elements 111–114 are temporary. Final names will be selected when the elements' discoveries are verified.

** Elements 116 and 118 were thought to have been created. The claim was retracted because the experimental results could not be repeated.

Europium 63 Eu 151.964	Gadolinium 64 Gd 157.25	Terbium 65 Tb 158.925	Dysprosium 66 Dy 162.500	Holmium 67 Ho 164.930	Erbium 68 Er 167.259	Thulium 69 Tm 168.934	Ytterbium 70 Yb 173.04	Lutetium 71 Lu 174.967
Americium 95 Am (243)	Curium 96 Cm (247)	Berkelium 97 Bk (247)	Californium 98 Cf (251)	Einsteinium 99 Es (252)	Fermium 100 Fm (257)	Mendelevium 101 Md (258)	Nobelium 102 No (259)	Lawrencium 103 Lr (262)

Use and Care of a Microscope



Eyepiece Contains magnifying lenses you look through.

Arm Supports the body tube.

Low-power objective Contains the lens with the lowest power magnification.

Stage clips Hold the microscope slide in place.

Coarse adjustment Focuses the image under low power.

Fine adjustment Sharpens the image under high magnification.

Body tube Connects the eyepiece to the revolving nosepiece.

Revolving nosepiece Holds and turns the objectives into viewing position.

High-power objective Contains the lens with the highest magnification.

Stage Supports the microscope slide.

Light source Provides light that passes upward through the diaphragm, the specimen, and the lenses.

Base Provides support for the microscope.

Caring for a Microscope

1. Always carry the microscope holding the arm with one hand and supporting the base with the other hand.
2. Don't touch the lenses with your fingers.
3. The coarse adjustment knob is used only when looking through the lowest-power objective lens. The fine adjustment knob is used when the high-power objective is in place.
4. Cover the microscope when you store it.

Using a Microscope

1. Place the microscope on a flat surface that is clear of objects. The arm should be toward you.
2. Look through the eyepiece. Adjust the diaphragm so light comes through the opening in the stage.
3. Place a slide on the stage so the specimen is in the field of view. Hold it firmly in place by using the stage clips.
4. Always focus with the coarse adjustment and the low-power objective lens first. After the object is in focus on low power, turn the nosepiece until the high-power objective is in place. Use ONLY the fine adjustment to focus with the high-power objective lens.

Making a Wet-Mount Slide

1. Carefully place the item you want to look at in the center of a clean, glass slide. Make sure the sample is thin enough for light to pass through.
2. Use a dropper to place one or two drops of water on the sample.
3. Hold a clean coverslip by the edges and place it at one edge of the water. Slowly lower the coverslip onto the water until it lies flat.
4. If you have too much water or a lot of air bubbles, touch the edge of a paper towel to the edge of the coverslip to draw off extra water and draw out unwanted air.

Matt Meadows

Diversity of Life: Classification of Living Organisms

A six-kingdom system of classification of organisms is used today. Two kingdoms—Kingdom Archaebacteria and Kingdom Eubacteria—contain organisms that do not have a nucleus and that lack membrane-bound structures in the cytoplasm of their cells. The members of the other four kingdoms have a cell or cells that contain a nucleus and structures in the cytoplasm, some of which are surrounded by membranes. These kingdoms are Kingdom Protista, Kingdom Fungi, Kingdom Plantae, and Kingdom Animalia.

Kingdom Archaebacteria

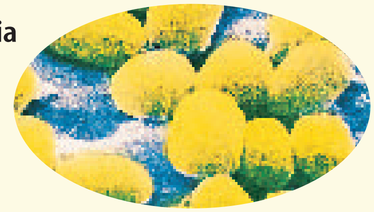
one-celled; some absorb food from their surroundings; some are photosynthetic; some are chemosynthetic; many are found in extremely harsh environments including salt ponds, hot springs, swamps, and deep-sea hydrothermal vents

Kingdom Eubacteria

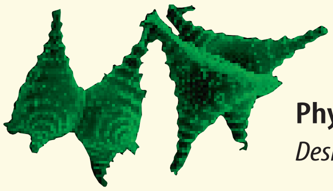
one-celled; most absorb food from their surroundings; some are photosynthetic; some are chemosynthetic; many are parasites; many are round, spiral, or rod-shaped; some form colonies

Kingdom Protista

Phylum Euglenophyta one-celled; photosynthetic or take in food; most have one flagellum; euglenoids



Kingdom Eubacteria
Bacillus anthracis



Phylum Chlorophyta
Desmids

Phylum Bacillariophyta one-celled; photosynthetic; have unique double shells made of silica; diatoms

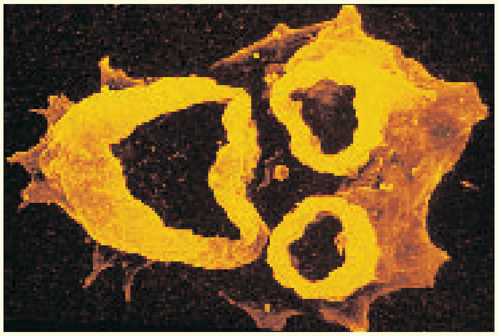
Phylum Dinoflagellata one-celled; photosynthetic; contain red pigments; have two flagella; dinoflagellates

Phylum Chlorophyta one-celled, many-celled, or colonies; photosynthetic; contain chlorophyll; live on land, in freshwater, or salt water; green algae

Phylum Rhodophyta most are many-celled; photosynthetic; contain red pigments; most live in deep, saltwater environments; red algae

Phylum Phaeophyta most are many-celled; photosynthetic; contain brown pigments; most live in saltwater environments; brown algae

Phylum Rhizopoda one-celled; take in food; are free-living or parasitic; move by means of pseudopods; amoebas



Amoeba

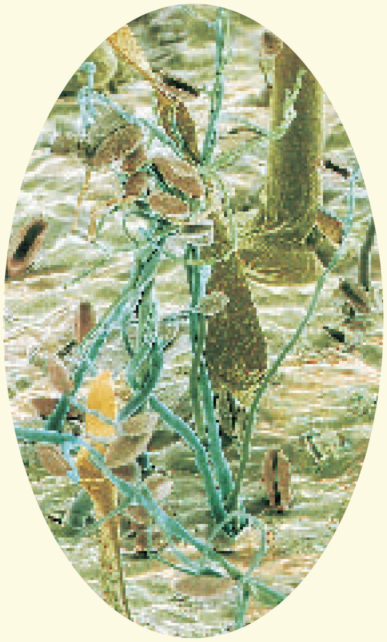
ich...ssel, (c)NIBSC/Science Photo Library/Photo Researchers, (r)David John/Visuals Unlimited

Phylum Zoomastigina one-celled; take in food; free-living or parasitic; have one or more flagella; zoomastigotes

Phylum Ciliophora one-celled; take in food; have large numbers of cilia; ciliates

Phylum Sporozoa one-celled; take in food; have no means of movement; are parasites in animals; sporozoans

Phylum Myxomycota
Slime mold



Phylum Oomycota
Phytophthora infestans

Phyla Myxomycota and Acrasiomycota one- or many-celled; absorb food; change form during life cycle; cellular and plasmodial slime molds

Phylum Oomycota many-celled; are either parasites or decomposers; live in freshwater or salt water; water molds, rusts and downy mildews

Kingdom Fungi

Phylum Zygomycota many-celled; absorb food; spores are produced in sporangia; zygote fungi; bread mold

Phylum Ascomycota one- and many-celled; absorb food; spores produced in asci; sac fungi; yeast

Phylum Basidiomycota many-celled; absorb food; spores produced in basidia; club fungi; mushrooms

Phylum Deuteromycota members with unknown reproductive structures; imperfect fungi; *Penicillium*

Phylum Mycophycota organisms formed by symbiotic relationship between an ascomycote or a basidiomycote and green alga or cyanobacterium; lichens

Lichens

(t)Runk/Schoenberger from Grant Heilman, (bl)Andrew Syred/Science Photo Library/Photo Researchers

Kingdom Plantae

Divisions Bryophyta (mosses), **Anthocerophyta** (hornworts), **Hepaticophyta** (liverworts), **Psilophyta** (whisk ferns) many-celled nonvascular plants; reproduce by spores produced in capsules; green; grow in moist, land environments

Division Lycophyta many-celled vascular plants; spores are produced in conelike structures; live on land; are photosynthetic; club mosses

Division Arthrophyta vascular plants; ribbed and jointed stems; scalelike leaves; spores produced in conelike structures; horsetails

Division Pterophyta vascular plants; leaves called fronds; spores produced in clusters of sporangia called sori; live on land or in water; ferns

Division Ginkgophyta deciduous trees; only one living species; have fan-shaped leaves with branching veins and fleshy cones with seeds; ginkgoes

Division Cycadophyta palmlike plants; have large, featherlike leaves; produces seeds in cones; cycads

Division Coniferophyta deciduous or evergreen; trees or shrubs; have needlelike or scalelike leaves; seeds produced in cones; conifers

Division Gnetophyta shrubs or woody vines; seeds are produced in cones; division contains only three genera; gnetum

Division Anthophyta dominant group of plants; flowering plants; have fruits with seeds

Kingdom Animalia

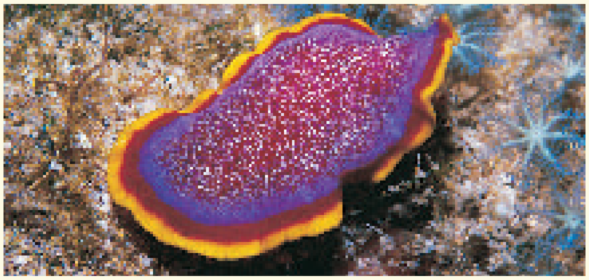
Phylum Porifera aquatic organisms that lack true tissues and organs; are asymmetrical and sessile; sponges

Phylum Cnidaria radially symmetrical organisms; have a digestive cavity with one opening; most have tentacles armed with stinging cells; live in aquatic environments singly or in colonies; includes jellyfish, corals, hydra, and sea anemones

Phylum Platyhelminthes bilaterally symmetrical worms; have flattened bodies; digestive system has one opening; parasitic and free-living species; flatworms

Division Anthophyta
Tomato plant

Division Bryophyta
Liverwort



Phylum Platyhelminthes
Flatworm

(tr)G.R. Roberts, (l)Ralph Reinhold/Earth Scenes, (br)Scott Johnson/Animals Animals

Phylum Chordata

Phylum Nematoda round, bilaterally symmetrical body; have digestive system with two openings; free-living forms and parasitic forms; roundworms

Phylum Mollusca soft-bodied animals, many with a hard shell and soft foot or footlike appendage; a mantle covers the soft body; aquatic and terrestrial species; includes clams, snails, squid, and octopuses

Phylum Annelida bilaterally symmetrical worms; have round, segmented bodies; terrestrial and aquatic species; includes earthworms, leeches, and marine polychaetes

Phylum Arthropoda largest animal group; have hard exoskeletons, segmented bodies, and pairs of jointed appendages; land and aquatic species; includes insects, crustaceans, and spiders

Phylum Echinodermata marine organisms; have spiny or leathery skin and a water-vascular system with tube feet; are radially symmetrical; includes sea stars, sand dollars, and sea urchins

Phylum Chordata organisms with internal skeletons and specialized body systems; most have paired appendages; all at some time have a notochord, nerve cord, gill slits, and a post-anal tail; include fish, amphibians, reptiles, birds, and mammals

Martin Harvey/DRK Photo

Cómo usar el glosario en español:
1. Busca el término en inglés que desees encontrar.
2. El término en español, junto con la definición, se encuentran en la columna de la derecha.

Pronunciation Key

Use the following key to help you sound out words in the glossary.

a	**back** (BAK)	**ew**	**food** (FEWD)
ay	**day** (DAY)	**yoo**	**pure** (PYOOR)
ah	**father** (FAH thur)	**yew**	**few** (FYEW)
ow	**flower** (FLOW ur)	**uh**	**comma** (CAH muh)
ar	**car** (CAR)	**u** (+ con)	**rub** (RUB)
e	**less** (LES)	**sh**	**shelf** (SHELF)
ee	**leaf** (LEEF)	**ch**	**nature** (NAY chur)
ih	**trip** (TRIHP)	**g**	**gift** (GIHFT)
i (i + con + e)	**idea** (i DEE uh)	**j**	**gem** (JEM)
oh	**go** (GOH)	**ing**	**sing** (SING)
aw	**soft** (SAWFT)	**zh**	**vision** (VIH zhun)
or	**orbit** (OR buht)	**k**	**cake** (KAYK)
oy	**coin** (COYN)	**s**	**seed, cent** (SEED, SENT)
oo	**foot** (FOOT)	**z**	**zone, raise** (ZOHN, RAYZ)

English — A — Español

aerobe (AY rohb): any organism that uses oxygen for respiration. (p. 10)

aerobio: cualquier organismo que utiliza oxígeno para respirar. (p. 10)

algae (AL jee): chlorophyll-containing, plantlike protists that produce oxygen as a result of photosynthesis. (p. 33)

algas: protistas parecidos a las plantas; contienen clorofila y producen oxígeno como resultado de la fotosíntesis. (p. 33)

anaerobe (AN uh rohb): any organism that is able live without oxygen. (p. 10)

anaerobio: cualquier organismo capaz de vivir sin oxígeno. (p. 10)

angiosperms: flowering vascular plants that produce fruits containing one or more seeds; monocots and dicots. (p. 79)

angiospermas: plantas vasculares que producen flores y frutos que contienen una o más semillas; pueden ser monocotiledóneas o dicotiledóneas. (p. 79)

antibiotics: chemicals produced by some bacteria that are used to limit the growth of other bacteria. (p. 15)

antibióticos: químicos producidos por algunas bacterias, utilizados para limitar el crecimiento de otras bacterias. (p. 15)

ascus (AS kus): saclike, spore-producing structure of sac fungi. (p. 46)

asca: estructura en forma de saco en donde los ascomicetos producen esporas. (p. 46)

auxin (AWK sun): plant hormone that causes plant leaves and stems to exhibit positive phototropisms. (p. 136)

auxina: hormona vegetal que causa que las hojas y tallos de las plantas desarrollen un fototropismo positivo. (p. 136)

B

basidium (buh SIH dee uhm): club-shaped, reproductive structure in which club fungi produce spores. (p. 46)

basidio: estructura reproductora en forma de mazo en la que los basidiomicetos producen esporas. (p. 46)

budding: form of asexual reproduction in which a new, genetically-identical organism forms on the side of its parent. (p. 46)

gemación: forma de reproducción asexual en la que se forma un organismo nuevo y genéticamente idéntico al lado de su progenitor. (p. 46)

C

cambium (KAM bee um): vascular tissue that produces xylem and phloem cells as a plant grows. (p. 77)

cellulose (SEL yuh lohs): chemical compound made out of sugar; forms tangled fibers in the cell walls of many plants and provides structure and support. (p. 64)

chlorophyll (KLOR uh fihl): green, light-trapping pigment in plant chloroplasts that is important in photosynthesis. (p. 126)

cilia (SIH lee uh): in protists, short, threadlike structures that extend from the cell membrane of a ciliate and enable the organism to move quickly. (p. 37)

cuticle (KYEW tih kul): waxy, protective layer that covers the stems, leaves, and flowers of many plants and helps prevent water loss. (p. 64)

cámbium: tejido vascular que produce las células del xilema y floema conforme crece la planta. (p. 77)

celulosa: compuesto químico formado por azúcares y que forma fibras intrincadas en la pared celular de muchas plantas proporcionando estructura y soporte. (p. 64)

clorofila: pigmento verde que absorbe luz y que se encuentra en los cloroplastos de las plantas; es importante para la fotosíntesis. (p. 126)

cilio: en los protistas, estructuras cortas en forma de hilo que se extienden desde la membrana celular de un ciliado y permiten al organismo moverse rápidamente. (p. 37)

cutícula: capa cerosa protectora que recubre el tronco, hojas y flores de muchas plantas y ayuda a prevenir la pérdida de agua. (p. 64)

D

day-neutral plant: plant that doesn't require a specific photoperiod and can begin the flowering process over a range of night lengths. (p. 138)

dicot: angiosperm with two cotyledons inside its seed, flower parts in multiples of four or five, and vascular bundles in rings. (p. 80)

planta de día neutro: planta que no requiere de un fotoperiodo específico y que puede comenzar su periodo de floración basándose en un rango de duración de las noches. (p. 138)

dicotiledónea: angiosperma con dos cotiledones dentro de su semilla, partes florales en múltiplos de cuatro o cinco y haces vasculares distribuidos en anillos. (p. 80)

E

endospore: thick-walled, protective structure produced by some bacteria when conditions are unfavorable for survival. (p. 19)

endospora: estructura protectora de pared gruesa que es producida por algunas bacterias cuando las condiciones son desfavorables para su supervivencia. (p. 19)

F

fission: simplest form of asexual reproduction in which two new cells are produced with genetic material identical to each other and identical to the previous cell. (p. 16)

flagellum: long, thin whiplike structure that helps organisms move through moist or wet surroundings. (pp. 15, 34)

fisión: la forma más simple de reproducción asexual en la que se producen dos nuevas células cuyo material genético es idéntico entre sí y al de la célula antecesora. (p. 16)

flagelo: estructura delgada y alargada en forma de látigo que ayuda a los organismos a desplazarse en medios acuosos. (pp. 15, 34)

frond: leaf of a fern that grows from the rhizome. (p. 100)

fronda: hoja de un helecho que crece a partir del rizoma. (p. 100)

G

gametophyte (guh MEE tuh fite) stage: plant life cycle stage that begins when cells in reproductive organs undergo meiosis and produce haploid cells (spores). (p. 97)

etapa de gametofito: etapa del ciclo de vida de las plantas que comienza cuando las células en los órganos reproductores, a través de la meiosis, producen células haploides (esporas). (p. 97)

germination: series of events that results in the growth of a plant from a seed. (p. 112)

germinación: serie de eventos que resultan en el crecimiento de una planta a partir de una semilla. (p. 112)

guard cells: pairs of cells that surround stomata and control their opening and closing. (p. 75)

células oclusoras: pares de células que rodean al estoma y que controlan su cierre y apertura. (p. 75)

gymnosperms: vascular plants that do not flower, generally have needlelike or scalelike leaves, and produce seeds that are not protected by fruit; conifers, cycads, ginkgoes, and gnetophytes. (p. 78)

gimnospermas: plantas vasculares que no florecen, generalmente tienen hojas en forma de aguja o de escama y producen semillas que no están protegidas por el fruto; se clasifican en coníferas, cicadáceas, ginkgoales y gnetofitas. (p. 78)

H

hyphae (HI fee): mass of many-celled, threadlike tubes forming the body of a fungus. (p. 44)

hifa: masa de tubos multicelulares en forma de hilos formando el cuerpo de los hongos. (p. 44)

L

lichen (LI kun): organism made up of a fungus and a green alga or a cyanobacterium. (p. 48)

liquen: organismo formado por un hongo y un alga verde o una cianobacteria. (p. 48)

long-day plant: plant that generally requires short nights—less than ten to 12 hours of darkness—to begin the flowering process. (p. 138)

planta de día largo: planta que generalmente requiere de noches cortas—menos de 12 horas de oscuridad—para comenzar su proceso de floración. (p. 138)

M

monocot: angiosperm with one cotyledon inside its seed, flower parts in multiples of three, and vascular tissues in bundles scattered throughout the stem. (p. 80)

monocotiledóneas: angiospermas con un solo cotiledón dentro de la semilla, partes florales dispuestas en múltiplos de tres y tejidos vasculares distribuidos en haces diseminados por todo el tallo. (p. 80)

mycorrhizae (mi kuh RI zee): network of hyphae and plant roots that helps plants absorb water and minerals from soil. (p. 48)

micorriza: estructura formada por una hifa y las raíces de una planta y que ayuda a las plantas a absorber agua y minerales del suelo. (p. 48)

N

nitrogen-fixing bacteria: bacteria that convert nitrogen in the air into forms that can be used by plants and animals. (p. 16)

nonvascular plant: plant that absorbs water and other substances directly through its cell walls instead of through tubelike structures. (p. 67)

bacterias fijadoras de nitrógeno: bacterias que convierten el nitrógeno presente en el aire en formas que pueden ser usadas por plantas y animales. (p. 16)

planta no vascular: planta que absorbe agua y otras sustancias directamente a través de sus paredes celulares en vez de utilizar estructuras tubulares. (p. 67)

O

ovary: swollen base of an angiosperm's pistil, where egg-producing ovules are found. (p. 107)

ovule: in seed plants, the female reproductive part that produces eggs. (p. 105)

ovario: base abultada del pistilo de una angiosperma donde se encuentran los óvulos productores de huevos. (p. 107)

óvulo: en las gimnospermas, la parte reproductiva femenina que produce huevos. (p. 105)

P

pathogen: disease-producing organism. (p. 19)

phloem (FLOH em): vascular tissue that forms tubes that transport dissolved sugar throughout a plant. (p. 77)

photoperiodism: a plant's response to the lengths of daylight and darkness each day. (p. 138)

photosynthesis (foh toh SIHN thuh suhs): process by which plants and many other producers use light energy to produce a simple sugar from carbon dioxide and water and give off oxygen. (p. 127)

pioneer species: first organisms to grow in new or disturbed areas; break down rock and build up decaying plant material so that other plants can grow. (p. 69)

pistil: female reproductive organ inside the flower of an angiosperm; consists of a sticky stigma, where pollen grains land, and an ovary. (p. 107)

pollen grain: small structure produced by the male reproductive organs of a seed plant; has a water-resistant coat, can develop from a spore, and contains gametophyte parts that will produce sperm. (p. 103)

patógeno: organismo que produce enfermedades. (p. 19)

floema: tejido vascular que forma tubos que transportan azúcares disueltos a toda la planta. (p. 77)

fotoperiodicidad: la respuesta de una planta a la duración de la luz y de la oscuridad cada día. (p. 138)

fotosíntesis: proceso mediante el cual las plantas y muchos otros organismos productores utilizan la energía luminosa para producir azúcares simples a partir de dióxido de carbono y agua y desprender oxígeno. (p. 127)

especies pioneras: los primeros organismos que crecen en áreas nuevas o alteradas; descomponen la roca y acumulan material vegetal en descomposición para que otras plantas puedan crecer. (p. 69)

pistilo: órgano reproductivo femenino en la flor de una angiosperma; consiste en un ovario y un estigma pegajoso donde caen los granos de polen. (p. 107)

grano de polen: estructura pequeña producida por los órganos reproductivos masculinos de los espermatófitos; tiene una cubierta resistente al agua, puede desarrollarse a partir de una espora y contiene partes del gametofito que producirán esperma. (p. 103)

pollination: transfer of pollen grains to the female part of a seed plant by agents such as gravity, water, wind, and animals. (p. 103)

prothallus (proh THA lus): small, green, heart-shaped gametophyte plant form of a fern that can make its own food and absorb water and nutrients from the soil. (p. 100)

protist: one- or many-celled eukaryotic organism that can be plantlike, animal-like, or funguslike. (p. 32)

protozoan: one-celled, animal-like protist that can live in water, soil, and living and dead organisms. (p. 37)

pseudopods (SEW duh pahdz): temporary cytoplasmic extensions used by some protists to move about and trap food. (p. 38)

polinización: transferencia de los granos de polen a la parte femenina de un espermatófito a través de agentes como la gravedad, el agua, el viento y los animales. (p. 103)

prótalo: gametofito pequeño de color verde en forma de corazón, de un helecho, que puede producir su propio alimento y absorber agua y nutrientes del suelo. (p. 100)

protista: organismo eucariota unicelular o pluricelular que puede parecerse a las plantas, a los animales o a los hongos. (p. 32)

protozoario: protista unicelular similar a los animales y que puede vivir en el agua, en el suelo y en los organismos vivos o muertos. (p. 37)

pseudópodos: extensiones citoplasmáticas temporales usadas por algunos protistas para moverse y atrapar alimento. (p. 38)

R

respiration: series of chemical reactions used to release energy stored in food molecules. (p. 129)

rhizoids (RI zoydz): threadlike structures that anchor nonvascular plants to the ground. (p. 68)

rhizome: underground stem. (p. 100)

respiración: serie de reacciones químicas usadas para liberar la energía almacenada en las moléculas de los alimentos. (p. 129)

rizoides: estructuras en forma de hilos que anclan las plantas no vasculares al suelo. (p. 68)

rizoma: tallo subterráneo. (p. 100)

S

saprophyte: organism that uses dead organisms as a food source and helps recycle nutrients so they are available for use by other organisms. (pp. 16, 44)

short-day plant: plant that generally requires long nights—12 or more hours of darkness—to begin the flowering process. (p. 138)

sori: fern structures in which spores are produced. (p. 100)

sporangium (spuh RAN jee uhm): round spore case of a zygote fungus. (p. 47)

spore(s): waterproof reproductive cell of a fungus that can grow into a new organism; in plants, haploid cells produced in the gametophyte stage that can divide by mitosis to form plant structures or an entire new plant or can develop into sex cells. (pp. 45, 97)

saprófito: organismo que usa a los organismos muertos como una fuente de alimento y ayuda a reciclar los nutrientes de tal forma que estén disponibles para ser usados por otros organismos. (pp. 16, 44)

planta de día corto: planta que generalmente requiere de noches largas—12 horas o más de oscuridad—para comenzar su proceso de floración. (p. 138)

soros: estructuras de los helechos en donde se producen las esporas. (p. 100)

esporangio: estructura redondeada que contiene las esporas de un zigomiceto. (p. 47)

espora(s): célula reproductora impermeable de un hongo, la cual puede convertirse en un nuevo organismo; en las plantas, las células haploides producidas en la etapa de gametofito que pueden dividirse por mitosis para formar las estructuras de la planta o una planta nueva, o que pueden convertirse en células sexuales. (pp. 45, 97)

sporophyte (SPOR uh fite) stage: plant life cycle stage that begins when an egg is fertilized by a sperm. (p. 97)

stamen: male reproductive organ inside the flower of an angiosperm; consists of an anther, where pollen grains form, and a filament. (p. 107)

stomata (STOH muh tuh): tiny openings in a plant's epidermis through which carbon dioxide, water vapor, and oxygen enter and exit. (pp. 75, 125)

etapa de esporofito: etapa del ciclo de vida de una planta que comienza cuando un huevo es fertilizado por un esperma. (p. 97)

estambre: órgano reproductor masculino dentro de la flor de una angiosperma, que consiste en un filamento y una antera donde se forman los granos de polen. (p. 107)

estoma: aperturas pequeñas en la superficie de la mayoría de las hojas de las plantas, las cuales permiten que entre y salga dióxido de carbono, agua y oxígeno. (pp. 75, 125)

T

toxin: poisonous substance produced by some pathogens. (p. 19)

tropism: positive or negative plant response to an external stimulus such as touch, light, or gravity. (p. 134)

toxina: sustancia venenosa producida por algunos patógenos. (p. 19)

tropismo: respuesta positiva o negativa de una planta a un estímulo externo como el rozamiento, la luz o la gravedad. (p. 134)

V

vaccine: preparation made from killed bacteria or damaged particles from bacterial cell walls or viruses that can prevent some bacterial and viral diseases. (p. 21)

vascular plant: plant with tubelike structures that move minerals, water, and other substances throughout the plant. (p. 67)

vacuna: preparación fabricada a partir de bacterias muertas o partículas dañadas de las paredes celulares bacterianas o virus y que puede prevenir algunas enfermedades bacterianas y virales. (p. 21)

planta vascular: planta con estructuras semejantes a tubos, las cuales sirven para movilizar minerales, agua y otras sustancias a toda la planta. (p. 67)

X

xylem (ZI lum): vascular tissue that forms hollow vessels that transport substances, other than sugar, throughout a plant. (p. 78)

xilema: tejido vascular que forma vasos ahuecados que trasportan todo tipo de sustancias, excepto azúcares, en toda la planta. (p. 78)

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Italic numbers = *illustration/photo* **Bold numbers = vocabulary term**
lab = *a page on which the entry is used in a lab*
act = *a page on which the entry is used in an activity*

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